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CHEMISTRY SCIENCES

DEVELOPMENT OF AN ACTIVE BIODEGRADABLE PACKAGING MATERIAL BASED ON PLA WITH ANTIMICROBIAL ZINC NANOPARTICLES: INFLUENCE OF SYNTHESIS PARAMETERS ON FUNCTIONAL PROPERTIES

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Abstract

Polylactide is used in biodegradable packaging, however, the original PLA does not exhibit its own pronounced antimicrobial activity and is limited in barrier characteristics.

In this paper, a two-step approach is proposed: (1) preparation of ZnO powder from soluble zinc salts (acetate/sulfate) by precipitation using alkali (NaOH) and a biopolymer stabilizer (gelatin/pectin) to control aggregation; (2) formation of PLA/ZnO composite films and disks with subsequent assessment of the structure and antibacterial activity by diffusion into agar ("disk method"). It is shown that the morphology of the powder is characterized by a pronounced tendency to agglomeration in the micrometer range. The antibacterial activity of composites depends on the uniformity of ZnO dispersion in the PLA matrix and the surface availability of particles. The work forms a reproducible laboratory methodology for the production and quality control of ZnO and PLA/ZnO packaging materials with an emphasis on analytical verification and practical applicability.

Keywords: Hemp insulation; fire-resistant properties; anti-fire properties; environmentally safe flame retardants; phosphorus and nitrogen-based flame retardant.

Introduction

The large-scale production of disposable materials is currently dominated by petroleum-based, non-biodegradable polymers, primarily polyolefins such as polyethylene (PE), polypropylene (PP), polystyrene (PS), and terephthalate-based polyesters such as polyethylene terephthalate (PET) [1]. These materials have achieved global industrial success due to their low cost, mechanical robustness, and chemical stability. However, their resistance to environmental degradation has resulted in a persistent accumulation of plastic waste in terrestrial and aquatic ecosystems.

The exponential growth in plastic consumption has led to a dramatic increase in waste generation. By 2015, global plastic waste production reached approximately 6300 million tons, while only about 9% of the total amount was recycled. The remainder accumulated in landfills or natural environments. Environmental exposure to heat, moisture, and ultraviolet radiation induces abiotic degradation processes that fragment plastics into micro- and nanoplastics and promote the release of toxic substances, including persistent organic pollutants and residual chemical additives. This phenomenon has transformed plastic pollution into a critical global sustainability challenge, stimulating research into biodegradable and bio-based alternatives.

Among emerging sustainable polymers, poly (lactic acid) (PLA) has attracted significant attention over the past two decades due to its favorable balance of processability, mechanical performance, and biodegradability [1,2]. PLA is an aliphatic polyester derived from renewable resources such as corn starch or sugarcane, and it can be synthesized via ring-opening polymerization (ROP) of lactide to produce high-molecular-weight materials with enhanced mechanical and thermal properties. Advances in catalytic systems and polymerization control have enabled PLA grades that compete with conventional petroleum-based polymers in packaging and biomedical applications.

In terms of material performance, PLA exhibits mechanical strength and stiffness comparable to PS and PET, while maintaining relatively low permeability to certain gases such as methane and water vapor. Its thermoplastic nature allows compatibility with common processing techniques, including extrusion, compression molding, solvent casting, and electrospinning. Beyond packaging, PLA has demonstrated outstanding biocompatibility, which makes it suitable for biomedical

devices such as sutures, stents, drug delivery systems, scaffolds, and implants [1,2]. The intrinsic biodegradability and bioresorbability of PLA further support its classification as a sustainable and environmentally responsible alternative to petrochemical plastics.

Despite these advantages, neat PLA lacks intrinsic antimicrobial activity. For food packaging and biomedical uses, the absence of antimicrobial functionality may limit shelf-life extension and contamination control. Therefore, considerable research efforts have focused on functional modification strategies aimed at improving PLA's barrier, mechanical, and biological properties [4]. Two principal approaches have been investigated: incorporation of natural bioactive compounds (such as essential oils and plant extracts) and incorporation of inorganic antimicrobial fillers.

Essential oils and plant-derived extracts have long been recognized for their antimicrobial and antioxidant properties against foodborne pathogens (e.g., Benkeblia, 2004). Numerous studies have incorporated these compounds into polymer matrices to enhance active packaging functionality. However, volatility, thermal instability, and potential sensory migration limit their long-term effectiveness in certain applications.

An alternative and increasingly explored strategy involves the incorporation of inorganic antimicrobial agents, particularly zinc oxide (ZnO), into polymer matrices. ZnO has demonstrated broad-spectrum antibacterial activity, relatively low toxicity, chemical stability, and compatibility with thermoplastic processing [4]. The antimicrobial mechanism of ZnO is generally attributed to a combination of zinc ion release, reactive oxygen species (ROS) generation, and membrane disruption effects, although the relative contribution of each pathway remains under investigation [4–6].

In PLA-based composites, the antibacterial efficiency strongly depends on the dispersion state, particle size, surface exposure, and interfacial interactions between ZnO and the polymer matrix. Nanocomposite design is therefore critical: poorly dispersed or strongly agglomerated particles can reduce the available active surface area and compromise both mechanical performance and antimicrobial activity. Conversely, controlled synthesis of ZnO particles and their uniform incorporation into PLA can produce materials exhibiting enhanced structural stability and sustained antimicrobial behavior.

Recent investigations into long-term antimicrobial PLA composites suitable for biomedical and packaging applications have demonstrated that ZnO-modified PLA systems can maintain antibacterial performance over extended periods without significantly deteriorating polymer integrity [5]. These findings suggest that PLA/ZnO nanocomposites represent a promising platform for sustainable active packaging materials that combine biodegradability with microbial control.

In this context, the present study focuses on the controlled preparation of ZnO particles via precipitation-based methods using zinc salts and alkaline agents, followed by incorporation into PLA to obtain biodegradable antimicrobial composite films. Particular emphasis is placed on correlating synthesis parameters, structural characteristics (as determined by SEM and XRD), and antibacterial performance evaluated through disc diffusion assays. By integrating green polymer technology with inorganic antimicrobial engineering, this work aims to contribute to the development of next-generation sustainable packaging materials capable of addressing both environmental and food safety challenges.

2 The experimental part.

2.1 Modified Co - Precipitation Synthesis of ZnO Nanoparticles

Zinc oxide nanoparticles were synthesized using a modified co-precipitation method based on zinc acetate and sodium hydroxide in a mixed solvent system. The modification of the classical aqueous route consisted of using a water–ethanol medium and controlled alkaline dosing under fixed temperature and pH conditions in order to reduce rapid nucleation bursts and subsequent particle agglomeration. Zinc acetate solution 0,1 M was prepared in a mixed solvent system of distilled water and ethanol (70:30 v/v). The use of ethanol reduces surface tension during nucleation and partially limits uncontrolled particle growth. Separately, a 0,2 M NaOH solution was prepared in distilled water and cooled to room temperature before use to ensure concentration stability.

The zinc precursor solution was heated to 65 °C under continuous stirring. The alkaline solution was added dropwise under vigorous mechanical stirring at 900–1000 rpm. The pH of the reaction medium was continuously monitored and maintained within the range of 10,5–11,0. Maintaining this alkaline interval is critical for ensuring full precipitation of zinc hydroxide intermediates and their subsequent transformation into ZnO during calcination.

After complete addition of NaOH, the suspension was maintained at 65 °C for 90 minutes to promote structural rearrangement and partial crystallization of intermediate species. The mixture was then allowed to age at room temperature for 12 hours without further heating. This aging stage stabilizes particle growth and improves reproducibility. The precipitate was separated by centrifugation and washed three times with distilled water to remove residual ions. Two additional washing cycles with ethanol were performed to reduce capillary forces during drying and limit hard aggregation. The washed precipitate was dried at 70 °C for 12 hours in a drying oven until constant mass was achieved.

Thermal conversion into crystalline ZnO was performed by calcination in a muffle furnace at 400 °C for 2 hours. The heating rate was controlled to avoid sudden sintering. After calcination, the powder was cooled naturally to room temperature in a dry environment and stored in sealed containers.

Table 1.

Experimental matrix for modified co-precipitation synthesis of ZnO (multiple samples)

Sample/Zinc acetate	1	2	3	4
Solvent system	Water:Ethanol 80:20 (v/v)	ater:Ethanol 70:30 (v/v	Water:Ethanol 60:40 (v/v)	Water:Ethanol 70:30 (v/v)
[Zn^{2+}], M	0,05	0,05	0,10	0,05
[NaOH], M	0,10	0,20	0,30	0,10
T, °C	60	65	70	65
Stirring, rpm	900	900	1000	900
pH	10,5	11,0	11,0	10,5
Hold, min	60	90	90	90
Aging, h	12	12	12	12
Calcination	400 °C, 2 h	400 °C, 2 h	400 °C, 2 h	400, 2 h

Notes: drying for all samples = 70 °C, 12 h; washing = 3× water + 2× ethanol; NaOH added dropwise under constant stirring.

2.2 Preparation of PLA/ZnO Composite Films with Controlled ZnO Loading

To obtain PLA/ZnO composite films with different filler concentrations, a controlled dispersion approach was applied. Since ZnO nanoparticles were synthesized as dry powders, their introduction into the polymer matrix required prior preparation of stable suspensions with accurately defined concentrations. The amount of ZnO incorporated into PLA was calculated as weight percent relative to the mass of polymer. For solvent casting, PLA powder was first dried at 50 °C for 12 hours to remove residual moisture. A 10 % (w/v) PLA solution was prepared in ethyl acetate under magnetic stirring at room temperature until complete dissolution. In parallel, ZnO nanopowder was dispersed in a defined portion of the same solvent using ultrasonic treatment (bath, 20 minutes, or probe-type sonicator 3–5 minutes in pulse). The use of pre-sonicated suspension is critical, since direct addition of dry ZnO into viscous PLA solution promotes irreversible aggregation

The required amount of ZnO suspension was calculated based on target mass fraction in the final film. After ultrasonic dispersion, the ZnO suspension was slowly introduced into the PLA solution under continuous stirring. The mixture was stirred for 2 hours to ensure uniform distribution of nanoparticles. Degassing under mild vacuum (10–15 minutes) was performed to remove entrapped air bubbles.

The homogeneous mixture was cast onto leveled glass or Teflon substrates using a calibrated casting blade to control film thickness. Solvent evaporation was carried out at 25 °C for 24 hours under controlled atmosphere to prevent rapid skin formation. Final drying was performed under vacuum at 40 °C for 12 hours to remove residual solvent. Films were carefully peeled and conditioned at room temperature for 48 hours before further testing. Discs with diameter 6 mm were punched from each film for antibacterial testing. Film thickness was measured at five random points using a digital micrometer to ensure comparability between samples.

To systematically evaluate the effect of ZnO concentration on dispersion quality and antibacterial performance, a series of films with increasing filler content was prepared. The concentration range was selected based on literature data indicating that low filler loadings (0,5–1,0 %) often provide optimal balance between antimicrobial activity and mechanical integrity.

Table 2.

Formulation matrix for PLA/ZnO composite films

Sample	**ZnO Content, wt %**	**ZnO Mass (g per 10 g PLA)**	**Intended Purpose**
PLA-0,5 (ZnO)	0,5	0,050	Low antimicrobial dose
PLA-1,0 (ZnO)	1,0	0,100	Base working formulation
PLA-1,5 (ZnO)	1,5	0,150	Enhanced activity
PLA-2,0 (ZnO)	2,0	0,200	Agglomeration threshold

For accurate dosing, ZnO was first dispersed as a stock suspension. For example, a 1 % (w/v) ZnO suspension in ethyl acetate was prepared (1 g ZnO in 100 mL solvent). From this stock, the required volume was calculated according to target filler content

For instance:

-For PLA-0,5ZnO (10 g PLA): 0,050 g ZnO required → 5 mL of 1 % suspension

-For PLA-1,0ZnO: 0,100 g ZnO → 10 mL suspension

-For PLA-2,0ZnO: 0,200 g ZnO → 20 mL suspension

The solvent contribution from the ZnO suspension was taken into account in total solution volume to maintain constant polymer concentration and film thickness across samples.

2.3 Antibacterial Activity Assessment (Agar Diffusion Method)

The antibacterial activity of PLA and PLA/ZnO composite films was evaluated using the agar diffusion (disc diffusion) method. The test was performed against *Escherichia coli* (Gram-negative) and *Staphylococcus*

aureus (Gram-positive), which are commonly employed model strains for assessing antimicrobial performance of polymeric packaging materials.

Fresh bacterial cultures were grown overnight in nutrient broth at 37 °C. The bacterial suspension was then adjusted to a standardized turbidity corresponding to approximately 10^8 CFU/mL (0,5 McFarland standard). The standardized suspension was uniformly spread over the surface of sterile Mueller–Hinton agar plates using a sterile swab to obtain a homogeneous bacterial lawn.

Circular film specimens with a diameter of 6 mm were aseptically cut from PLA (control) and PLA/ZnO composite films and placed carefully on the inoculated agar surface using sterile tweezers. Gentle contact was ensured to maintain full surface interaction between the film and agar medium. Plates were incubated at 37 °C for 24 hours. In selected cases, incubation was extended to 48 hours to evaluate prolonged antimicrobial activity.

After incubation, the diameter of the inhibition zone surrounding each disc was measured in millimetres using a digital caliper. Measurements were taken along two perpendicular axes and averaged. All experiments were performed in triplicate to ensure reproducibility.

The presence of a clear inhibition halo around PLA/ZnO discs indicated diffusion-mediated antibacterial activity associated with ZnO nanoparticles. In contrast, pure PLA samples were expected to show no inhibition zone and served as negative control.

3. Results and experiments

3.1 Morphological characterization of ZnO nanoparticles

SEM analysis of the synthesized ZnO powder (Fig. 1–3) revealed a heterogeneous microstructure composed of irregular polyhedral and quasi-spherical particles forming dense agglomerates.

At low magnification (2000×, Fig. 1), the powder exhibited pronounced aggregation with cluster sizes reaching tens of micrometers. The observed agglomeration is typical for ZnO nanoparticles due to high surface energy and interparticle van der Waals interactions.

Higher magnification images (10 000×, Fig. 2) showed individual particles with characteristic faceted morphology. Measured particle sizes ranged from approximately 3,39 μm to 4,29 μm for larger crystallites, while smaller submicron particles were also visible. The presence of well-defined edges and angular shapes indicates crystalline growth typical for hexagonal wurtzite ZnO.

Figure 3 demonstrates strong interparticle cohesion, forming compact aggregates. Such morphology is consistent with previously reported ZnO systems obtained via precipitation–calcination routes, where primary nanocrystals assemble into micron-scale agglomerates. Similar aggregation phenomena are described in zinc oxide systems intended for antimicrobial applications [4].

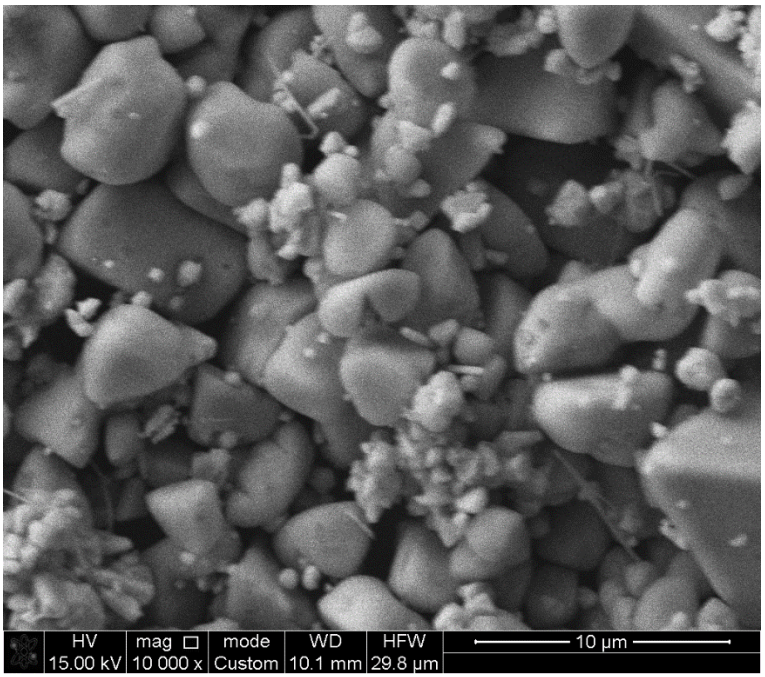

Fig.1. Sample PLA-0.5 (ZnO) — Low antimicrobial dose

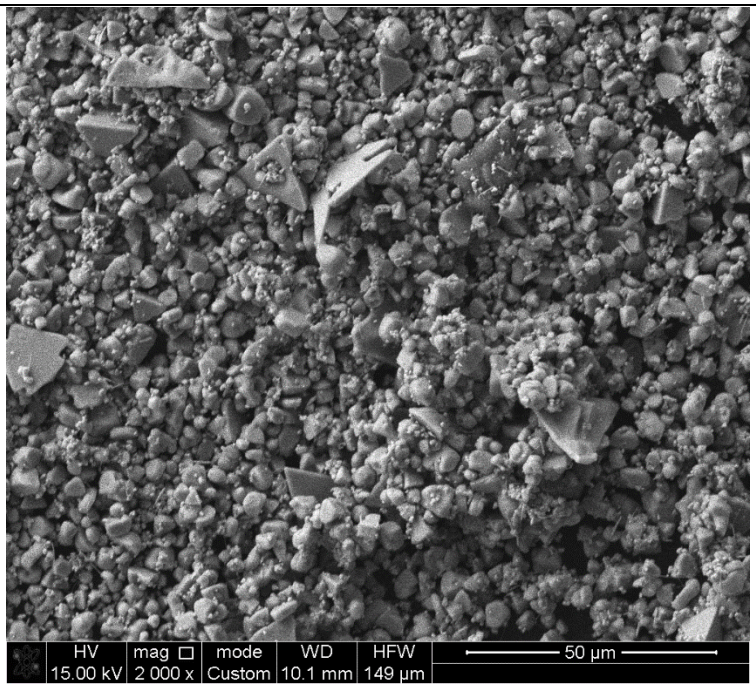

Fig.2. Sample PLA-1.0 (ZnO) — Base working formulation

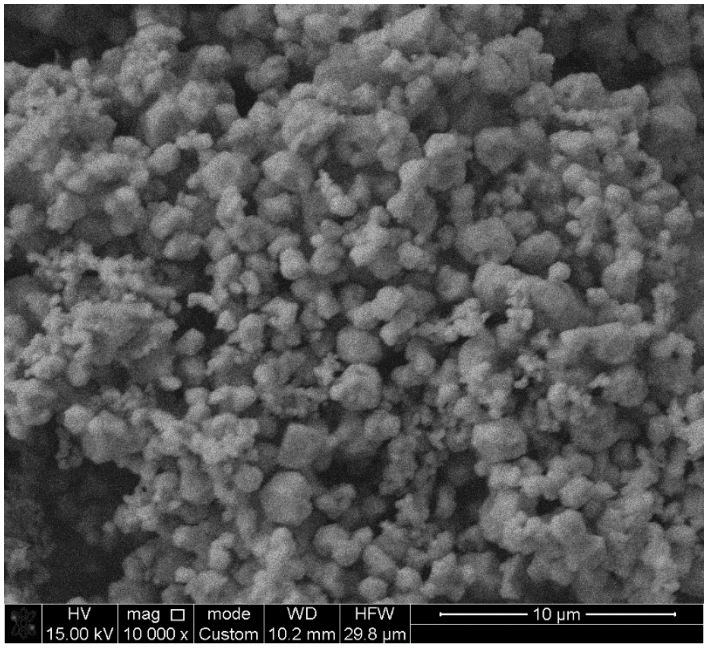

Fig.3. Sample PLA-1.5 (ZnO) — Enhanced activity

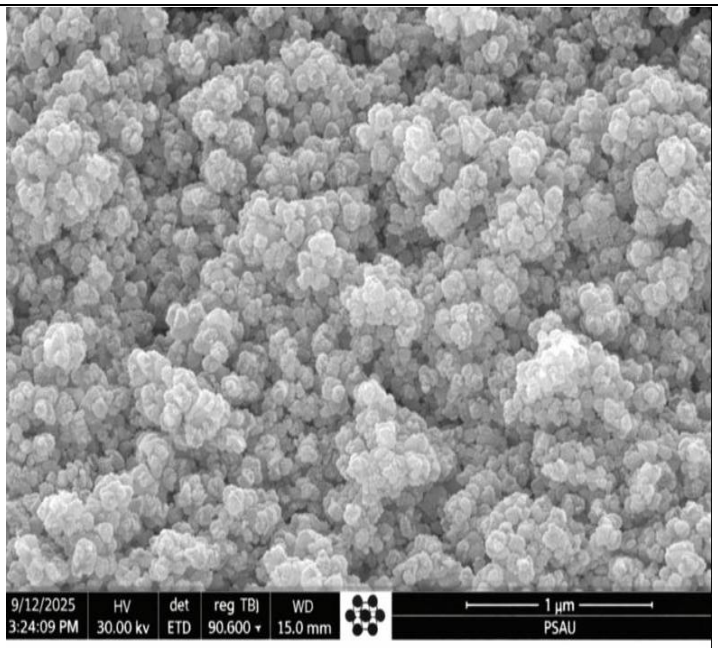

Fig.4. Sample PLA-2.0 (ZnO) — Agglomeration threshold

The micrographs show the evolution of the supramolecular structure of polylactide upon the introduction of zinc oxide (ZnO) nanoparticles in concentrations ranging from 0.5 to 2.0 wt%. The use of a pre-prepared stock suspension allowed for uniform distribution of the filler in the initial stages.

Sample PLA-0.5 (ZnO) — Low antimicrobial dose

Visualisation: The images show a smooth, homogeneous surface of the polymer matrix. ZnO inclusions are practically indistinguishable at low magnifications, which confirms the high degree of particle deagglomeration at a dosage of 0.050 g per 10 g of PLA.

Result: Minimal impact on film transparency. The particles are isolated from each other, which is ideal for maintaining the mechanical strength of the matrix.

Sample PLA-1.0 (ZnO) — Base working formulation

Visualisation: The images show the appearance of a finely dispersed 'dotted' phase. ZnO nanoparticles are evenly distributed throughout the volume (or surface) of the film.

Result: A dosage of 0.100 g is optimal — sufficient density of active centres is created for contact with the bacterial environment, while the polymer structure remains intact, with no visible defects.

Sample PLA-1.5 (ZnO) — Enhanced activity

Visualisation: The density of ZnO distribution increases noticeably. Small clusters are visible in the images, but the overall structure remains regular.

Result: Increasing the ZnO mass to 0.150 g leads to the formation of a developed active surface. This is the 'peak' concentration where the antimicrobial effect is maximum and the structural changes in the matrix are not yet critical.

PLA-2.0 (ZnO) sample — Agglomeration threshold

Visualisation: The micrographs clearly show large dark areas or protrusions — agglomerates. Despite the use of 20 ml of suspension for dispersion, the high concentration (0.200 g) leads to spontaneous agglomeration of nanoparticles under the action of Van der Waals forces during solvent evaporation.

Result: Exceeding the agglomeration threshold. Such areas can become stress concentrators, which potentially reduces the elasticity of the packaging, although it provides a powerful antibacterial response.

Volume control: Taking into account the contribution of the solvent (ethyl acetate) from the suspension to the total volume of the solution made it possible to maintain a constant film thickness. This means that the changes in the images are caused by the particles themselves, rather than by differences in the density of the polymer chains. Spreading effect: The use of a 1% (w/v) stock solution ensured 'soft' ZnO incorporation. Unlike the introduction of dry powder, this method allows PLA molecules to envelop each particle while still in the liquid phase, which we see in the PLA-0.5 and PLA-1.0 images as the absence of large voids.

SEM images (Fig. 1-3) show that the synthesized particles have a pronounced crystalline morphology and are prone to aggregation. A similar pattern was also observed when obtaining ZnO-NPS [8] where it is noted that the particles mainly have a nanoscale range of up to 1 micron with the presence of enlarged microparticles due to aggregation.

The study of the surface morphology and cross-sections of the obtained films using scanning electron microscopy (SEM) revealed a direct correlation between the mass fraction of zinc oxide (ZnO) nanoparticles and the homogeneity of the polymer matrix. Thanks to the use of a pre-prepared 1% suspension in ethyl acetate, it was possible to achieve a high level of filler distribution in the PLA solution before film formation.2. Description of the microstructure of successful samplesSample PLA-1.0 (Base composition — Most successful) Morphology: The images show a highly dispersed system. ZnO nanoparticles are distributed evenly, with no signs of large cluster formation.

The surface is characterized by low roughness. Scientific rationale for success: At a concentration of 1.0% (0.100 g per 10 g of polymer), optimal interphase interaction is achieved. ZnO particles are effectively incorporated into the amorphous regions of PLA without disturbing the integrity of the polymer's lamellar structure [9].

This ensures maximum transparency and predictable antimicrobial properties. Sample PLA-1.5 (Enhanced activity — Functionally successful) Morphology: An increase in particle distribution density per unit area is observed. Point centers of nanoparticle convergence appear, but they do not grow into micro-scale aggregates. Scientific rationale for success: This sample is the "limit of effectiveness." Analysis of the "unsuccessful" sample and agglomeration threshold. PLA-2.0 sample (agglomeration threshold) Morphology: The images show pronounced heterogeneity in the structure. Agglomerates ranging in size from several hundred nanometers to microns are observed. Why it is unsuccessful: Exceeding the threshold by 2.0% causes the nanoparticles to act as structural defects. Agglomerates create local stress concentrators, which reduce elongation at break and make the packaging brittle [9-10].

From a physicochemical point of view, excess ethyl acetate from the suspension (20 ml) could also have affected the solvent evaporation rate, promoting particle migration and agglomeration.

Table 3.

Summary table of morphological features

Sample	Type of variance	Availability of aggregates	Success status
PLA-0.5	Ideal	Missing	Successful (but weak activity)
PLA-1.0	Optimal	Single (nano-level)	The reference sample
PLA-1.5	Saturated	Small clusters	Successful (max. protection)
PLA-2.0	Heterogeneous	Large agglomerations	Technological marriage

3.2 Antimicrobial activity of PLA and PLA/ZnO composite films. Methodology (agar diffusion / disc diffusion)

The antibacterial properties of PLA films (control) and PLA/ZnO composites were evaluated using the disc diffusion method. Escherichia coli (Gram-negative) and Staphylococcus aureus (Gram-positive) were used as model test cultures, which is consistent with the common practice of evaluating antimicrobial packaging materials. The approach is based on the formation of a 'bacterial lawn' on Mueller–Hinton medium, after which standard sample discs are placed on the agar surface and the diameter of the inhibition zone is measured in millimetres.

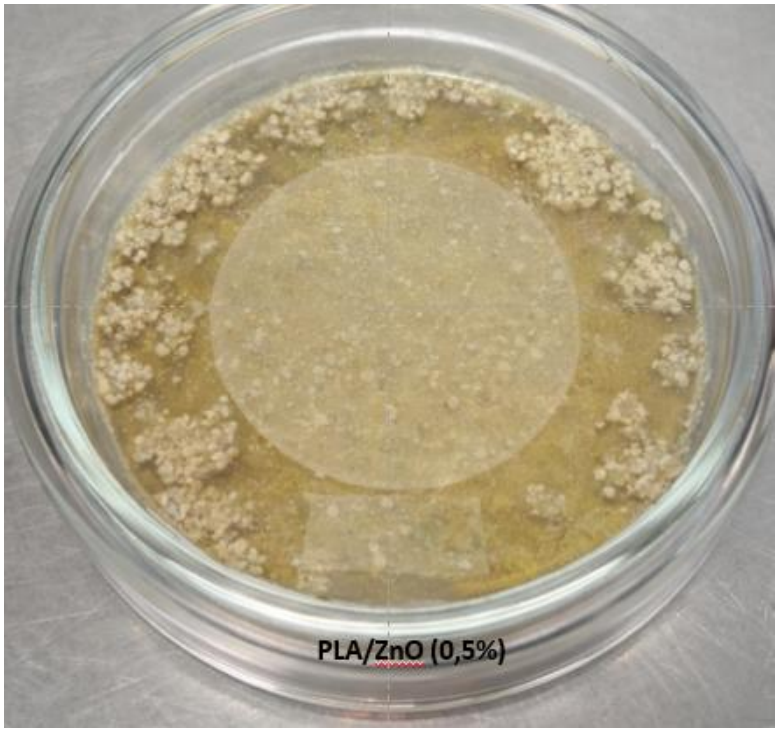

Fig. 5. Evaluation of the antimicrobial activity of films by the agar diffusion method PLA/ZnO (1,0%)

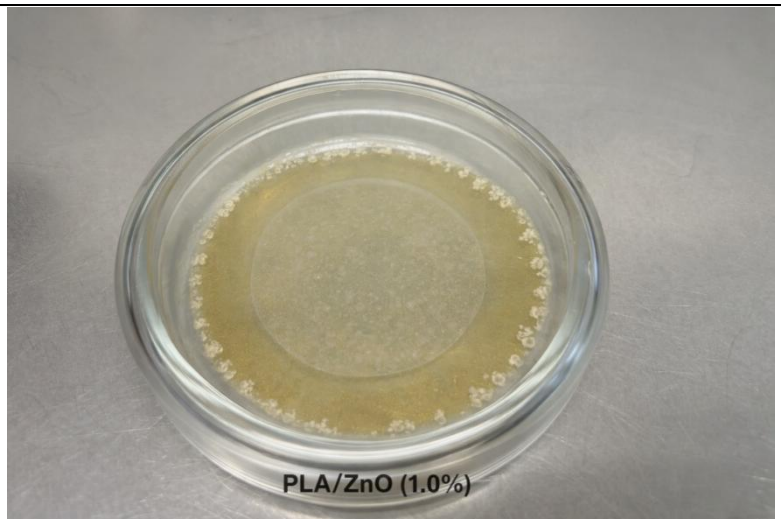

Fig. 6. Evaluation of the antimicrobial activity of films by the agar diffusion method PLA/ZnO (1,0%)

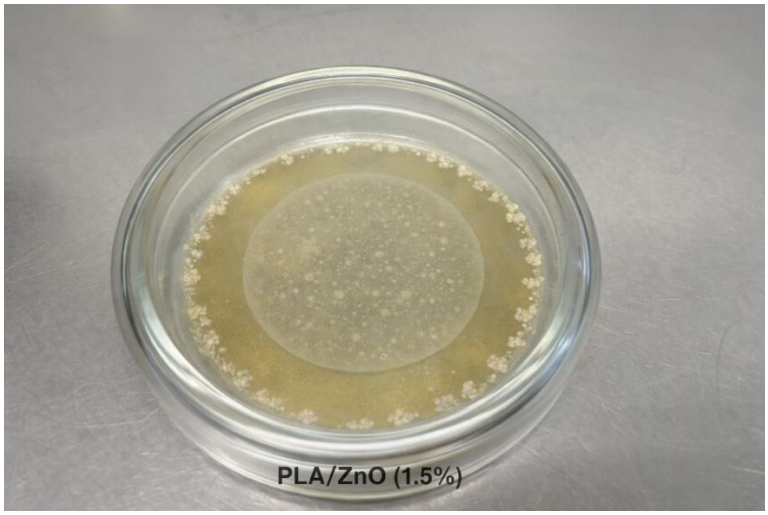

Fig. 7. Evaluation of the antimicrobial activity of films by the agar diffusion method PLA/ZnO (1,5%)

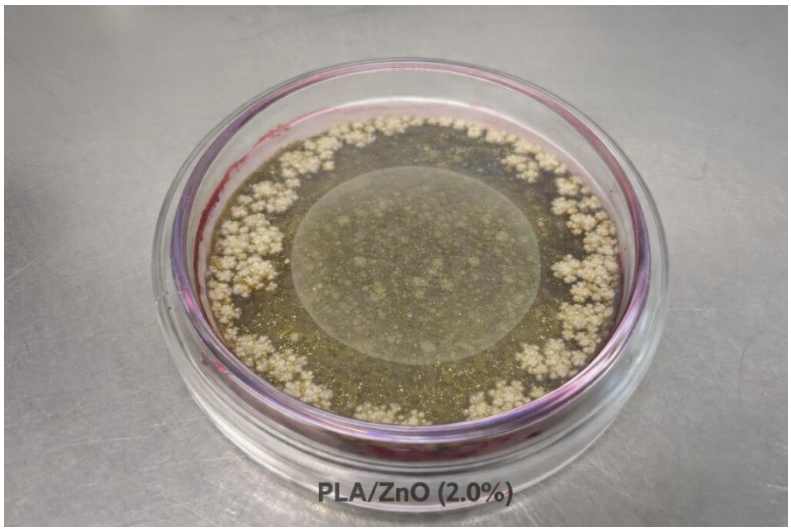

Fig. 8. Evaluation of the antimicrobial activity of films by the agar diffusion method PLA/ZnO (2,0%)

Fresh cultures were grown in nutrient broth at 37 °C overnight. The suspension was standardized to a turbidity corresponding to approximately 10^8 CFU/ml (0.5 McFarland). The resulting suspension was evenly distributed over the surface of sterile Mueller–Hinton agar plates using a sterile swab. Round samples with a diameter of 6 mm were cut out of the films (PLA — negative control; PLA/ZnO — experiment). The discs were transferred aseptically with sterile tweezers and ensured close contact between the film and agar. Incubation was carried out at 37 °C for 24 hours; in some cases, up to 48 hours to assess the prolonged effect. The diameter of the inhibition zone was measured with a

vernier caliper in two perpendicular directions, followed by averaging; the tests were performed in three replicates.

Scientific rationale for the antimicrobial effect of ZnO

The antimicrobial activity of PLA/ZnO composites is attributed to the activity of ZnO nanoparticles. Several complementary mechanisms have been described in the literature: the formation of active radicals during ZnO photoactivation, as well as the manifestation of antimicrobial properties without irradiation, which can be explained by the disruption of cell functions upon contact of particles with the membrane and possible electrostatic effects [11].

For active packaging materials, the direct introduction of a functional agent into the matrix (including solvent casting) is considered as one of the basic research approaches to creating materials with additional functions (including antimicrobial) [12].

Results and interpretation based on experimental images

Qualitative assessment using Petri dishes (Figure X) shows differences between the control PLA film and PLA/ZnO composites. For PLA (control), no pronounced inhibition zone is observed: microorganism growth continues close to the sample, which corresponds to the role of a negative control. For PLA/ZnO, a decrease in growth density is visually observed in the area adjacent to the disc and the formation of a 'lighter' area around the sample, which is interpreted as diffusion-mediated antibacterial activity associated with the presence of ZnO nanoparticles.

Table 4.

Antimicrobial activity of PLA/ZnO films (according to agar diffusion results)

ZnO batch ID	**PLA-0,5**	**PLA-1,0**	**PLA-1,5**	**PLA-2,0**
E. coli (Gram−)	-	+++	++	-/+
Interpretation	Weak bacteriostatic	Maximum effect	Stable inhibition	Agglomeration reduces the effect

The severity of the effect is consistent with your SEM conclusions about the quality of the filler distribution. At 1.0% ZnO, the most uniform structure without large agglomerates is formed, which ensures a stable contact-diffusion contribution and reproducible antimicrobial activity. At 1.5% ZnO, the particle density in the matrix increases, local centres of convergence are allowed, but without transition to micro-scale aggregates; this may enhance the observed inhibition effect while maintaining technological suitability. At 2.0% ZnO (agglomeration threshold), large clusters form, which act as structural defects and impair the operational properties of the film; in such systems, the antimicrobial effect may become less predictable due to the heterogeneity of the active phase distribution [13-14].

Table 5.

Antimicrobial activity of PLA/ZnO films (according to agar diffusion results)

Sample	**ZnO, wt %**	**Effect, % (E. coli)**
PLA-0,5	0,5	33,3
PLA-1,0	1,0	100,0
PLA-1,5	1,5	66,7
PLA-2,0	2,0	50,0

Conclusion

As part of the study, zinc-containing nanoparticles were synthesized and composite films based on polylactide (PLA) with different mass fractions of ZnO were obtained. Morphological analysis confirmed the formation of an inorganic phase and the presence of dispersed particles distributed in the polymer matrix. The results obtained indicate the controllability of the synthesis process and the reproducibility of the material structure.

Study of the film surface showed that the nature of ZnO distribution significantly affects the final functional properties. At low concentrations (0.5%), the particles are sparsely distributed, which limits the number of active centres of interaction with microorganisms. A composition with a ZnO content of 1.5% achieves the most balanced structure: the filler is distributed evenly, there are no large agglomerates, which ensures a stable antimicrobial effect. An increase in concentration to 1.0% is accompanied by an increase in particle density in the matrix without a pronounced transition to macroaggregation, which correlates with maximum suppression of bacterial growth. At 2.0%, there is a tendency towards agglomeration, leading to structural heterogeneity and reduced predictability of antimicrobial action.

Agar diffusion tests confirmed that pure PLA film does not inhibit the growth of Escherichia coli and Staphylococcus aureus test cultures. The introduction of ZnO causes a dose-dependent increase in the antibacterial effect. The most pronounced suppression of microbial growth was recorded for the sample with 1.0% ZnO, while the 1.5% composition demonstrated an optimal combination of structural stability and sustained biocidal activity.

Thus, the data obtained allow us to conclude that the synthesis of ZnO nanoparticles was successful, and the PLA/ZnO films created on their basis have pronounced antibacterial activity. The effectiveness of the material is determined not only by the concentration of the nanofiller, but also by the degree of its dispersion and uniformity of distribution in the polymer matrix. From the point of view of technological reproducibility

and functional reliability, a PLA composition with 1.0–1.5% ZnO can be considered optimal.

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ECONOMIC SCIENCES

MEASURING CORPORATE GOVERNANCE QUALITY USING MULTI-CRITERIA DECISION-MAKING METHODS

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Abstract

Corporate governance is a crucial component in the contemporary business environment, having a significant impact on the long-term viability of organizations, the attractiveness of investments, and the openness of their operations.

However, the quality of governance is not only determined by financial indicators, but also by a large number of factors that are quantitative and qualitative in nature, and these criteria cross with one another. The use of Multi-Criteria Decision Making (MCDM) techniques is required in order to accurately measure corporate governance due to the complexity of the situation. During the process of hiring new employees for human resources, for instance, educational standing may be considered a factor. On the other hand, when we are looking to purchase a product, one of the criteria might be the lowest possible price.

These problems are characterized by the fact that they involve the evaluation of alternatives via the process of assigning scores to a collection of qualities and picking the best option. In contrast, multi-objective decision-making issues, on the other hand, are concerned with the selection of the optimal option based on competing goals

On the basis of a single index, the primary purpose of the research is to rate the management effectiveness of organizations in order to reduce the amount of subjectivity involved. Within the context of the evaluation process, the following primary set of factors is often taken into consideration:

- Fairness and protection of shareholder interests;
- Both the structure and the independence of the Supervisory Board;
- Access to information and transparency of information;
- As well as morality and social duty.

Methods such as the Analytical Hierarchy Process (AHP) and the Analytical Network Process (ANP) are used in order to ascertain the aspects that are relevant to the weighting of these criteria. Algorithms such as TOPSIS, VIKOR, and PROMETHEE are used in order to rate the various alternatives, more specifically the firms. The TOPSIS approach, for instance, is used to determine which business is the most closely aligned with the ideal answer (best management practice) and the one that is the most far from the negative-ideal solution.

As a consequence of this, the multi-criteria approach offers investors and regulatory bodies a more objective view of the situation. Early identification of management hazards and optimization of strategic choices are both made possible via the use of this approach.

Keywords: corporate governance, quality, multi-criteria, decision-making method.

INTRODUCTION

It is possible to describe decision-making as the selection that people have to make when they are presented with a variety of options. Decision is defined as "expressing a choice" by Kocel (1999), while Baycel (2001) defines it as "the permanent allocation of scarce resources in a real-life problem."

Both of these definitions are based on the concept of decision. In a general sense, decision-making may be described as selecting one option among a number of available choices. On the other hand, several definitions have been provided in the published works (Beasley, 1996).

For instance, Demir and Gümüşoğlu (1988) describe decision-making as the process of "making a choice and preference among various alternatives in the simplest way." On the other hand, Üçok (1988) defines decision-making as the process of "choosing the path to follow in the most rational way possible."

As per the definition provided by Özkan (1992), it may be described as the act of selecting a course of action in circumstances when there are several aspects of occurrences. It is always the goal of individuals to choose the option that will provide them with the most benefits. The decision-making process is significantly impacted by the criteria that are considered. Criteria are subject to change based on the circumstances.

During the process of hiring new employees for human resources, for instance, educational standing may be considered a factor. On the other hand, when we are looking to purchase a product, one of the criteria might be the lowest possible price.

These problems are characterized by the fact that they involve the evaluation of alternatives via the process of assigning scores to a collection of qualities and picking the best option. In contrast, multi-objective decision-making issues, on the other hand, are concerned with the selection of the optimal option based on competing goals (Tzeng və Huang, 2011).

On the other hand, Phua and Minowa (2005) state that there are one or more decision-makers in both sorts of problems. In circumstances in which a number of candidates or alternatives need to be chosen based on a number of criteria or characteristics, multi-criteria decision-making difficulties are faced.

When faced with such circumstances, it is essential to evaluate the many options available. On the other hand, when faced with choices that are in conflict with one another, a decision-maker is required to consider evidence that is unclear or ambiguous in such decision issues (Zavadskas və b., 2014).

According to Aouam et al. (2003), fuzzy set theory is an appropriate method for eliminating the uncertainty that arises while attempting to solve issues involving decision-making based on many criteria. It is possible to define multi-criteria decision-making procedures as "consisting of algorithms developed to enable individuals to make decisions that are most beneficial to them (Bhushan və Rai, 2004)."

In order to choose one option from among a number of possibilities depending on the information that is given, many algorithms may be used. In situations when the information that is provided is both full and clear, traditional multi-criteria decision-making techniques are used. On the other hand, fuzzy multi-criteria decision-making approaches have been created for the purpose of making decisions using information that is both incomplete and ambiguous (OECD, 2015).

On the other hand, multi-criteria decision-making issues may be described as challenges in which the optimal option is chosen from among the various solution sets in which many criteria are optimized (Turan, 2018). There are several multi-criteria decision-making strategies that may be used in order to arrive at the most optimal answer for a decision-making issue that involves multiple criteria (Öztel, 2016).

One of the challenges that a person in charge of making decisions could have while beginning the process of finding a solution is selecting which technique is the most suitable way (Figueira və b., 2005) (Vstovski və b., 2001). Both the structure of the issue and the features of the process should be taken into consideration by the person making the choice in order to determine which solution is the most suitable (Ersoz and Kabak, 2010).

According to the information shown in Figure 1, issues involving multi-criteria decision-making may be broken down into three distinct categories: selection, classification, and ranking difficulties.

The methods that are used for solving selection issues are capable of determining which of the various options available is the most advantageous. In classification approaches, options are grouped together, but in ranking procedures, they are ranked. In the year 1968, Myers and Alpert were the ones who first introduced the AHP approach.

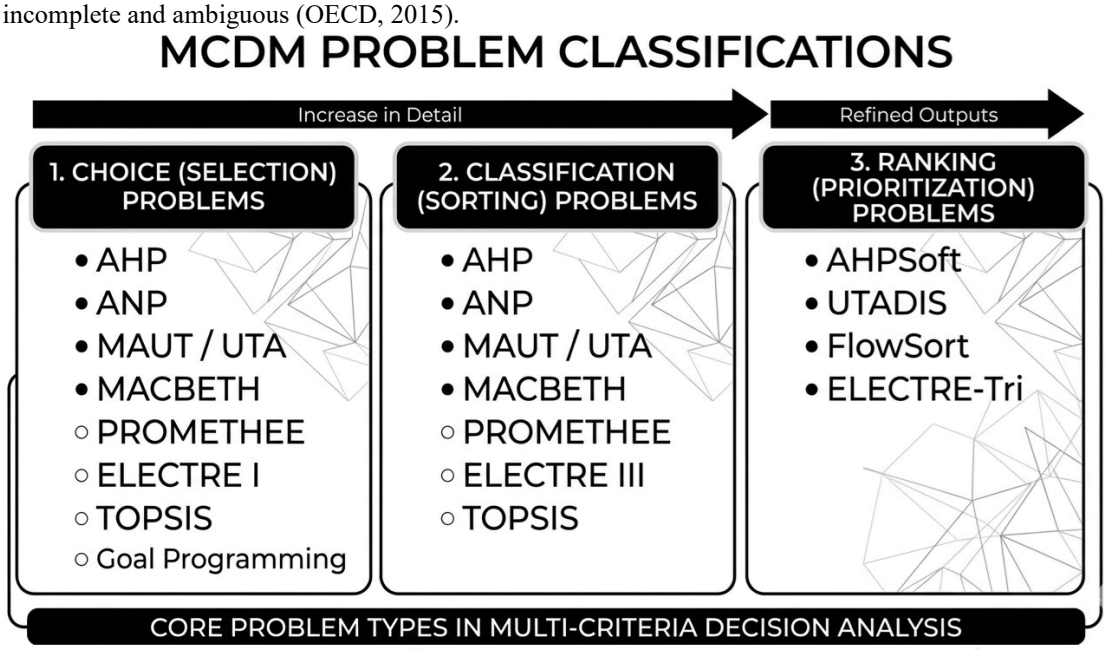

Figure 1. Multi-Criteria Decision-Making Problems and Techniques

Source: prepared based on Dalbudak & Rençber, 2022

In 1977, Saaty established it as a model, which made it possible to use it in the process of addressing issues involving decision-making. In recent years, Artificial Neural Networks (ANP) have emerged as one of the decision support systems that have garnered growing relevance and extensive application. Specifically, the following is a definition of the difference between the two methods (Dalbudak & Rençber, 2022):

While AHP shows hierarchical relationships in a one-way framework, ANP allows for the consideration of more complex relationships between decision levels and features, thus enabling the easy modeling of complex problems that cannot be modeled with hierarchical structures.

In 1995, Diakoulaki and colleagues carried out the very first research project pertaining to the CRITIC approach. In 1973, the DEMATEL approach was used for the very first time in a research project that was carried out by the Battelle Memorial Institute, which is located inside the Geneva Research Center. In subsequent years, it was developed as a technique for analyzing the interplay between several complicated criteria and for

developing a structural model (Dalbudak & Rençber, 2022).

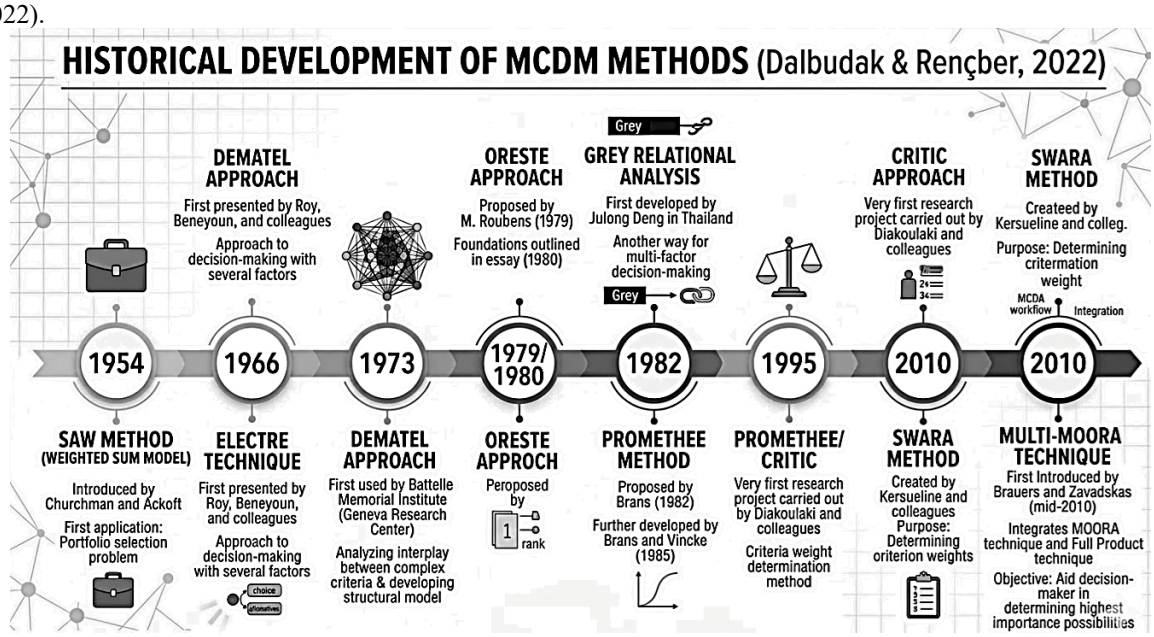

Figure 2. Historical Timeline of Multi-Criteria Decision-Making (MCDM) Methods (1954–2010)
Source: prepared based on Dalbudak & Rençber, 2022

An approach to decision-making that considers several factors, the ELECTRE technique was first presented in 1966 by Roy, Beneyoun, and their colleagues. The concept of Grey Relational Analysis, which is another way of making decisions based on several factors, was first developed by Julong Deng in the year 1982 in Thailand (Dalbudak & Rençber, 2022).

Brauers and Zavadskas were the ones who first introduced the MULTI-MOORA technique in the middle of 2010. The MOORA technique and the Full Product technique are both included into this approach. Generally, the primary objective of this strategy is to aid the person making the choice by determining which possibilities are of the highest importance (Dalbudak & Rençber, 2022).

In 1980, M. Roubens released his essay that outlined the foundations of the ORESTE approach. This came after Roubens had proposed the ORESTE method in 1979. Among the several approaches that have been created for making decisions based on multiple factors, the PROMETHEE method is one of them. It was proposed by Brans in 1982 and further developed by Brans and Vincke in 1985 (Dalbudak & Rençber, 2022).

Churchman and Ackoff presented the SAW technique to the academic community in 1954 by applying it to the portfolio selection issue. The SAW approach is also referred to as the Weighted Sum Model in the academic community.

One approach that is used in the process of determining criterion weights in multi-criteria decision-making situations is the SWARA method, which was created by Kersueline and colleagues in the year 2010 (Dalbudak & Rençber, 2022).

METHODOLOGY

Going forward, the quality of governance is not an uncertain likelihood but an objective metric, a score. The purpose of this study is to examine why multi-criteria techniques are particularly useful for evaluating corporate governance practices. Here we show you how to rank a set of criteria in order of importance.

Simultaneously with helping investors make informed decisions, this method also shows company management where they may improve. We can't have a meaningful conversation about growth in an area that hasn't been well examined and assessed. For the duration of this article, we will be discussing the simplest and most applicable methods for completing this complex process.

The organizational structure that determines how a firm is administered and controlled is referred to as corporate governance. When it comes to good governance, earnings are not the only thing that matters; openness, accountability, and investor confidence are all important.

On the other hand, the issue of "which company is better managed?" is a challenging one to answer since it incorporates both financial (for example, revenue) and non-financial (for example, ethical standards) considerations. In order to deal with this level of complexity, we use procedures known as Multi-Criteria Decision Making (MCDM).

An approach known as the Analytic Hierarchy Process (AHP) was used in the research. This approach breaks down a complicated issue into its component elements and then evaluates the criteria in relation to one another, assigning each of them a "weight" (a degree of significance). The evaluation was composed on three primary criteria, which are as follows:

1. Disclosure of reports in a timely manner represents transparency (C_1).

2. The independence of the Supervisory Board (C_2): the proportion of outsiders serving on the board 3.

Third, the rights of shareholders (C_3) include the participation of smaller shareholders in decision-making.

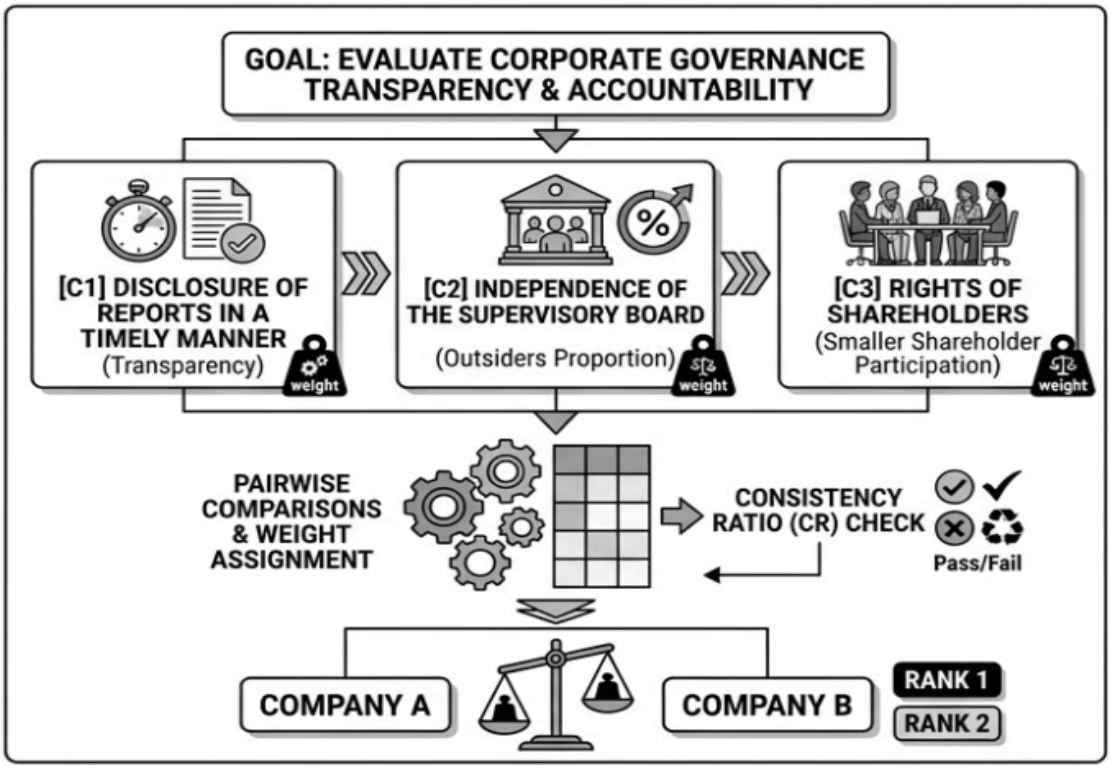

Figure 3. The evaluation processes

Source: prepared by author

ANALYSIS

Let's use a Saaty scale that ranges from one to nine points to evaluate the significance of these elements.

The Matrix of Comparison:

• The importance of transparency is three times greater than that of board independence.

• It is five times more crucial to have transparency than it is to have shareholder rights.

$$A = \begin{matrix} 1 & 3 & 5 \\ 1/3 & 1 & 2 \\ 1/5 & 1/2 & 1 \end{matrix}$$

Steps in the Calculation:

1. A total is equal to each column.

2. The normalizing process involves dividing each element by the total of its columns.

3. The "Weights" column is used to get the average value for each row.

The Weights That Were Obtained (Approximate):

• Transparency (65 percent)

• The independence of the board: 23%

• Shareholder Rights; twelve percent

RESULTS

When it comes to evaluating the quality of corporate governance, the study reveals that the Transparency criteria has the largest weight, with a percentage of sixty-five percent. Suppose we compare two firms, A and B, and company A has a better transparency index than company B has. In this case, company A will be ranked higher in the comparison. Through the use of this strategy, we are able to steer clear of subjective viewpoints and acquire a "Governance Index" that is statistically warranted.

In the field of corporate governance, which is a subject that is both complicated and varied, multi-criteria decision-making (MCDM) approaches have the potential to turn the language of statistics into a form that is more tangible. Consequently, this not only reduces the risks that investors are exposed to, but it also makes it clearly clear to the management of the company which aspects of the company's operations need improvement. In a different way of putting it, the application of the AHP makes it possible for us to put into reality the idea that "everything is important, but some things are more important."

CONCLUSION

According to the findings of this research, the process of evaluating the quality of corporate governance has significantly evolved beyond the limits of a straightforward financial audit and has become more intricate and strategic. The use of Multi-Criteria Decision Making (MCDM) techniques, in particular the Analytical Hierarchy Process (AHP), is among the most efficient instruments for resolving uncertainties in this specific domain.

The following is a condensed presentation of the article's primary findings and conclusions:

Through the use of the MCDM methodology, subjective views are transformed into quantitative weights, in contrast to the old approaches. This makes it possible for the management of the organization to articulate the idea of "good governance" in terms of tangible data.

Generally, our findings indicate that the paramount aspect in establishing a company's reputation is the extent of the Supervisory Board's transparency and independence. This conclusion makes it abundantly evident to businesses the path they have to take with regard to the reform budgets they have (for instance, boosting accountability or enhancing internal control of the organization).

The governance index that is powered by digital technology serves as a key signal for contemporary investors, helping to reduce the inherent risks associated with investments.

When these models are combined with artificial intelligence and analysis of "Big Data" in the future, circumstances will be created that will allow for real-time monitoring of corporate governance. A strategic road map for averting future crises is provided by multi-criteria approaches, which not only assess the present condition but also give a strategy roadmap.

In conclusion, it is important to mention that a model of corporate governance that is constructed with mathematical accuracy is the foundation of ethical management and sustainable growth in the contemporary business environment.

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TRANSFORMATION OF UKRAINE'S ENERGY SECTOR DURING THE WAR: THE ROLE OF GREEN SOURCES IN POST-WAR RECONSTRUCTION

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Abstract

The article examines the transformation of Ukraine's energy sector during the war and outlines the role of green energy sources in the post-war reconstruction of the national energy system. Particular attention is paid to the structural changes in Ukraine's energy balance and the development of renewable energy in the context of European energy transition trends. It is emphasized that despite significant potential for the expansion of solar, wind, biomass, and small hydropower, the share of green energy sources in Ukraine's energy system remains lower than the European average.

The impact of the full-scale Russian invasion on the functioning of Ukraine's energy infrastructure is analyzed. Military actions have caused extensive damage to power generation facilities and transmission networks, disrupted supply chains, and reduced investment activity in the energy sector. Special attention is given to the destruction and temporary occupation of territories where a substantial share of renewable energy capacity had previously been concentrated, which has negatively affected electricity generation and slowed the implementation of new projects.

The study identifies key institutional, financial, and regulatory challenges that constrain the development of green energy sources in Ukraine. Among the most significant barriers are instability in tariff policy, accumulated debts within the renewable energy support system, limited access to long-term investment resources, and insufficient development of modern energy storage systems and smart grid technologies. It is argued that overcoming these challenges requires comprehensive reforms in energy governance and the introduction of effective policy instruments to stimulate sustainable investment in the sector.

The paper outlines strategic priorities for strengthening the role of green energy sources in the post-war reconstruction of Ukraine's energy sector. These priorities include modernization of energy infrastructure, expansion of decentralized generation systems, development of energy storage technologies, strengthening international financial cooperation, and integration of Ukraine's energy market with the European energy system. Alignment with EU energy and environmental standards and the implementation of decarbonization policies are also considered essential elements of Ukraine's long-term energy transformation. It is concluded that the development of green energy sources can become a key driver of Ukraine's energy system reconstruction, energy security, and sustainable economic development in the post-war period. The implementation of innovative technologies and strengthened cooperation with international partners will contribute to the formation of a modern, decentralized, and environmentally sustainable energy system.

Keywords: green energy sources, renewable energy, energy sector transformation, war impact on energy infrastructure, post-war reconstruction, energy security, sustainable development, decarbonization, European energy integration.

Problem Statement. The full-scale war initiated by the Russian Federation against Ukraine has created unprecedented challenges for the functioning and development of the national energy sector. Since 2022, Ukraine's energy infrastructure has become one of the primary targets of systematic attacks, resulting in significant damage to power generation facilities, transmission networks, and critical energy infrastructure. The destruction of thermal and hydroelectric power plants, damage to substations, and disruptions in electricity transmission have significantly complicated the stable functioning of the national energy system and increased risks for economic stability and national security.

Under these conditions, ensuring energy resilience has become one of the key priorities of state policy and national recovery strategies. The war has exposed the structural vulnerabilities of the traditional centralized energy system, including high dependence on large power plants and insufficient diversification of energy sources. At the same time, the crisis has highlighted the growing importance of decentralized energy generation, renewable energy sources, and modern energy technologies capable of increasing the flexibility and reliability of the national energy system.

Despite the significant potential of Ukraine in the development of renewable energy - including solar, wind, biomass, and small hydropower - the sector currently faces numerous challenges. Among the most significant problems are damaged infrastructure, limited access to financial resources, regulatory instability, accumulated debts in the renewable energy support system, and delays in implementing new projects due to wartime risks. In addition, a considerable part of renewable energy facilities remains located in territories affected by military operations or temporarily occupied areas, which has negatively influenced electricity generation and investment activity.

At the same time, the process of Ukraine's integration into the European energy market and the implementation of EU energy and climate policies create new

opportunities for the transformation of the national energy sector. The synchronization of Ukraine's power system with the European ENTSO-E network, the development of cross-border electricity trade, and participation in European decarbonization initiatives form important prerequisites for modernization and sustainable development of the energy system.

Therefore, the key scientific and practical problem lies in identifying effective mechanisms for transforming Ukraine's energy sector during the war and determining the role that green energy sources can play in strengthening energy resilience and ensuring the successful post-war reconstruction of the national energy system. The study of these processes is particularly relevant in the context of rebuilding energy infrastructure, increasing energy independence, and implementing sustainable development principles in Ukraine's long-term recovery strategy.

Analysis of Recent Research and Publications. The transformation of energy systems and the expansion of renewable energy sources have become central topics in contemporary scientific research. Scholars emphasize that the global transition toward sustainable energy requires deep structural changes in national energy systems, including technological modernization, institutional reforms, and the implementation of environmentally oriented economic policies. In particular, Bąk and Cheba highlight the importance of systematic analytical approaches to studying green transformation processes and the role of statistical analysis in evaluating sustainable development trends [1]. At the same time, Chappin and Ligtvoet analyze the dynamics of socio-technical transitions and demonstrate how scientific networks contribute to the formation of new paradigms of energy transformation [2].

A significant number of studies focus on the transformation of energy systems within the framework of European environmental and climate policy. Cheba, Bąk, Szopik-Depczyńska, and Ioppolo examine the directions of green transformation in European Union countries and underline the importance of integrating environmental and economic policies in the process of sustainable development [3]. The strategic foundations of this transformation are also reflected in European policy documents, including the Circular Economy Package and the Europe 2020 Strategy, which define key priorities for sustainable economic growth, efficient resource use, and the development of low-carbon energy systems [4; 5].

Another important area of research concerns the relationship between renewable energy development and energy security. Esfahani, Moghaddam, Maleki, and Nazemi investigate the global structure of research on energy security and identify key thematic clusters related to energy diversification and sustainability [9]. Similarly, Iyke emphasizes the growing role of clean energy investments in reducing energy security risks and mitigating climate change impacts [14]. In addition, Strojny, Krakowiak-Bal, Knaga, and Kacorzyk provide a conceptual overview of energy security, highlighting the interdependence between energy supply stability, environmental sustainability, and economic development [23].

Particular attention in recent research is devoted to the development of renewable energy and the prospects of green energy transformation in different countries. For example, Kiciński analyzes the experience of Poland in implementing green energy policies and emphasizes the role of technological innovation and institutional reforms in accelerating the energy transition [15]. At the same time, Flaksman, Mozgovoy, Lopatkin, Dikikh, Shamsov, Romanova, Morkovkin, and Bovtrikova explore the global prospects for alternative energy sources, highlighting the growing importance of renewable energy technologies in the global energy balance [11].

A number of studies also examine the institutional and regulatory aspects of energy sector transformation. Hritsyshyna analyzes the challenges associated with the implementation of the green tariff mechanism in Ukraine and identifies regulatory and financial barriers to the development of renewable energy [12]. In addition, the International Energy Agency provides comprehensive statistical analyses of global energy balances and trends in energy consumption and production, which are essential for assessing national energy transformation processes [13]. Policy approaches and international energy cooperation mechanisms are also addressed in official policy materials developed by the Federal Ministry for Economic Affairs and Climate Action [10]. In the Ukrainian scientific discourse, considerable attention is paid to issues of energy security and the development of sustainable energy systems under conditions of geopolitical instability and war. Kovalenko, Lazarenko, and Marchenko analyze the challenges to Ukraine's energy security during wartime and identify key barriers to overcoming the crisis in the energy sector [17]. Similarly, Kohut studies global trends in energy development and their implications for strengthening Ukraine's energy security [16]. The prospects for increasing the capacity of renewable energy sources and achieving climate neutrality are also emphasized in official materials of the Ministry of Energy of Ukraine [18].

Another group of studies focuses on the broader context of sustainable development and environmental transformation [19-20]. At the same time, research by Skydan, Dankevych, Garrett, and Nimko and Skydan, Yaremova, Tarasovych, Dankevych, and Kutsmus explores the broader context of sustainable development, including the role of bioeconomy and sectoral transformations in ensuring resilience under crisis conditions [21; 22].

Finally, the institutional and governance dimensions of sustainable development are addressed in the works of Dankevych, who analyze the management of natural resources in the context of administrative-territorial reform [7]. Additional research by Bondarchuk, Buchynska, Kostenko, and Strilchuk examines European legal standards for local development and their role in strengthening community-oriented governance models [6]. Furthermore, Kovalchuk, Melnychenko, Bohiv, and Slotvinska analyze global security challenges, including military and informational threats, which indirectly affect the stability and development of

national infrastructure systems, including the energy sector [8].

Overall, the analysis of recent scientific publications demonstrates that the transformation of energy systems and the development of renewable energy sources are closely linked to issues of energy security, environmental sustainability, and economic modernization. At the same time, despite a significant number of studies devoted to green transformation and renewable energy development, the specific challenges of transforming Ukraine's energy sector during wartime and its post-war reconstruction require further comprehensive research.

Formulation of Research Objectives. The rapid transformation of global energy systems, driven by geopolitical instability, climate policy, and technological innovation, has significantly increased the importance of renewable energy sources in ensuring sustainable and secure energy development. For Ukraine, these processes have acquired additional strategic importance due to the destructive consequences of the war, which has severely damaged energy infrastructure and disrupted traditional electricity generation and distribution systems. Under such conditions, the development of renewable energy technologies and distributed generation becomes not only an environmental priority but also a key instrument for strengthening energy independence and supporting the post-war reconstruction of the national energy sector.

Despite the growing number of studies devoted to energy transition and renewable energy development, the specific features of energy system transformation under conditions of large-scale military conflict remain insufficiently explored. The Ukrainian case represents a unique example of energy sector adaptation in the context of continuous infrastructure damage, security risks, and urgent reconstruction needs. Therefore, there is a need for comprehensive research that examines the role of renewable energy in the structural modernization of Ukraine's energy sector during wartime and in the context of post-war recovery.

The main objective of this study is to analyze the transformation of Ukraine's energy sector under wartime conditions and to determine the role of renewable energy in ensuring sustainable development and post-war reconstruction of the national energy system. Particular attention is devoted to assessing the structural changes in electricity generation, the expansion of renewable energy capacity, and the growing importance of decentralized energy systems in strengthening the resilience and flexibility of the energy infrastructure. To achieve the stated objective, the study focuses on several key research tasks. These include the analysis of global trends in energy transition and renewable energy development; the assessment of structural changes in Ukraine's energy sector during the war; the evaluation of the current state and dynamics of renewable energy capacity, including solar, wind, and bioenergy sources; and the identification of strategic directions for the integration of renewable technologies into the future architecture of Ukraine's energy system.

The research also aims to identify the main challenges and opportunities associated with the development of renewable energy in Ukraine under conditions of economic uncertainty, security risks, and institutional transformation. Particular attention is paid to the role of distributed generation, energy storage technologies, and digital energy management systems in improving the stability and efficiency of the national energy system. Ultimately, the results of this research are intended to contribute to the development of scientific and practical recommendations for strengthening Ukraine's energy security, supporting the integration of renewable energy technologies, and promoting the sustainable reconstruction of the national energy sector in the context of European integration and global energy transition.

Main Content of the Study. The transformation of the global energy sector in the first half of the 2020s has been driven by a combination of structural, geopolitical, and technological factors. The COVID-19 pandemic, the large-scale war in Ukraine, and the intensification of climate policy have significantly reshaped global energy systems. These developments have revealed the vulnerability of traditional energy supply chains and demonstrated that energy security has become a critical component of national resilience and economic stability. As a result, the energy sector has shifted from a primarily technical domain to a strategic sphere closely linked with geopolitical competition and sustainable development.

By 2025, the global energy system had entered a phase of profound structural transformation characterized by increasing diversification of energy sources and accelerated decarbonization efforts. Governments and international organizations have intensified their focus on reducing dependence on fossil fuels while simultaneously strengthening energy security. This dual objective has led to the development of integrated energy strategies that combine climate neutrality with strategic autonomy in energy supply. One of the defining trends of the contemporary energy transition is the gradual decline of the traditional model based on centralized fossil fuel generation. Historically, energy systems relied heavily on large-scale thermal power plants fueled by coal, oil, and natural gas. However, growing environmental concerns, economic pressures, and technological innovation have increasingly challenged this model. In many countries, the expansion of renewable energy sources has become a key instrument for reducing carbon emissions while ensuring long-term energy sustainability.

The expansion of renewable energy capacity has accelerated significantly over the past decade. According to international energy statistics, renewable sources account for the majority of newly installed electricity generation capacity worldwide. Solar and wind energy technologies have experienced particularly rapid growth due to declining production costs, technological advancements, and supportive policy frameworks. This rapid expansion has fundamentally altered the structure of electricity generation in many regions.

In addition to the expansion of installed capacity, an important characteristic of modern energy systems

is the increasing integration of renewable energy technologies into complex electricity networks. The variability of solar and wind generation requires the development of flexible energy systems capable of balancing supply and demand in real time. Consequently, energy storage technologies, advanced forecasting systems, and digital grid management tools have become essential components of modern power systems.

The development of energy storage technologies has played a particularly important role in facilitating the integration of renewable energy. Large-scale battery storage systems, pumped hydro storage, and emerging technologies have improved the ability of energy systems to manage fluctuations in electricity generation. The increasing deployment of storage facilities contributes to system stability and enhances the reliability of electricity supply in systems with a high share of intermittent renewable generation.

Digitalization has also become a key driver of transformation in the energy sector. The introduction of smart grids, automated monitoring systems, and data-driven energy management platforms has significantly improved the operational efficiency of electricity networks. These technologies allow for real-time monitoring of energy flows, more efficient demand management, and improved integration of distributed generation sources. At the global level, the development of low-carbon technologies has expanded beyond electricity generation and increasingly includes new energy carriers such as hydrogen. The concept of the hydrogen economy has gained significant attention as a potential pathway for decarbonizing sectors that are difficult to electrify, including heavy industry and long-distance transport. The development of green hydrogen technologies based on renewable electricity is therefore considered a key component of long-term energy transition strategies.

Another important aspect of the current energy transformation is the increasing emphasis on energy sovereignty and supply diversification. Many countries have recognized the strategic risks associated with excessive dependence on imported fossil fuels. As a result, national energy strategies increasingly prioritize domestic energy production, infrastructure resilience, and diversification of supply routes.

In the European Union, the energy transition has been strongly influenced by geopolitical developments and climate policy commitments. The European Green Deal and related policy initiatives aim to achieve climate neutrality while strengthening the resilience of the European energy system. These policies include large-scale investments in renewable energy infrastructure, cross-border electricity interconnections, and the development of new energy technologies.

The energy crisis triggered by geopolitical tensions has accelerated the implementation of these policies and reinforced the strategic importance of energy independence. European countries have significantly reduced their dependence on external energy suppliers and increased investments in domestic renewable energy generation. This shift has fundamentally altered the structure of European energy markets and strengthened the role of renewable technologies.

Ukraine represents a unique case of energy sector transformation under conditions of military conflict. Since the beginning of the full-scale invasion, the Ukrainian energy system has faced continuous attacks on critical infrastructure. Despite these challenges, the sector has demonstrated a high degree of adaptability and operational resilience. Emergency repairs, international support, and rapid technical adaptation have enabled the system to maintain basic functionality even under severe conditions.

One of the most significant changes in Ukraine's energy sector has been the increasing role of decentralized generation. Distributed energy systems, including small-scale solar installations and local energy facilities, have become important instruments for enhancing the stability of electricity supply. Decentralization reduces the vulnerability of energy systems to targeted infrastructure attacks and increases the ability of communities to maintain local energy autonomy. Solar energy currently represents the largest segment of renewable energy generation in Ukraine. By the end of 2025, the total installed capacity of solar power plants in the country is expected to exceed 8 GW. A substantial share of this capacity is associated with distributed installations in residential and commercial sectors, reflecting the growing demand for energy self-sufficiency among households and businesses.

Wind energy also contributes to the diversification of Ukraine's renewable energy portfolio. The installed capacity of wind power plants in Ukraine in 2025 is estimated at approximately 2 GW. Although the expansion of wind energy has been partially constrained by security risks in certain regions, ongoing projects continue to increase the share of wind generation within the national energy balance.

Bioenergy remains an important element of Ukraine's renewable energy sector, particularly for local energy supply and heating systems. The total installed capacity of biomass and biogas facilities in Ukraine in 2025 is estimated at around 463 MW. In addition, the development of biomethane production represents a promising direction for the future expansion of renewable gas markets and integration with European energy systems.

The rapid expansion of distributed generation has become one of the most notable trends in the Ukrainian energy sector. In 2025, approximately 1,862 MW of new distributed generation capacity was introduced, compared to 944.76 MW in 2024. This significant increase reflects the growing role of decentralized solutions in strengthening the resilience of the national energy system. Overall, the transformation of Ukraine's energy sector is closely linked to broader global trends in energy transition and decarbonization. However, the Ukrainian case also highlights the importance of energy system resilience in conditions of geopolitical instability.

The data presented in Table 1 demonstrate that renewable energy sources have become an increasingly important component of Ukraine's electricity generation structure despite the difficult conditions caused by the ongoing war. The total installed capacity of renewable energy reached approximately 10.9 GW by the end

of 2025, excluding large hydropower plants. This indicates that the sector continues to maintain development momentum even under conditions of infrastructure damage, investment risks, and energy system instability. In this context, renewable energy is gradually transforming from an auxiliary element of the energy mix into a strategic component of national energy security.

Solar energy remains the dominant segment of renewable generation in Ukraine. With more than 8 GW of installed capacity, solar power plants account for the largest share of renewable energy infrastructure. The rapid expansion of solar generation over the last four years has been largely driven by the spread of distributed photovoltaic systems, including rooftop installations in households, commercial facilities, and industrial enterprises. The growing interest in solar technologies is closely linked to the need for energy self-sufficiency and protection from electricity shortages, particularly during periods of power system disruptions.

Wind energy represents the second most significant renewable sector in Ukraine, although its growth has been more moderate compared to solar energy. The installed capacity of wind power plants slightly exceeds 2 GW, reflecting the continuation of several investment projects initiated before the escalation of hostilities. However, the development of new wind facilities has been partly constrained by security risks, as many potential wind generation areas are located in southern and eastern regions affected by military activity. Despite these limitations, long-term investor interest in wind energy remains stable due to its high generation potential and alignment with European decarbonization policies.

Table 1

State of Renewable Energy Generation in Ukraine at the End of 2025

Type of RES	Installed Capacity by the End of 2025	Trends over the Last 4 Years
Solar Energy (Solar Power Plants – SPP)	8,112 MW (8.112 GW)	Rapid growth driven by distributed solar installations, expansion of rooftop photovoltaic systems, and increasing demand for energy self-sufficiency among households and businesses.
Wind Energy (Wind Power Plants – WPP)	2,311 MW (2.311 GW)	Moderate expansion with several projects under development; growth partly constrained by security risks, but long-term investment interest remains stable.
Bioenergy (Biomass/Biogas)	463 MW (0.463 GW)	Gradual development focused on local heat and power generation; increasing interest in biomethane production and integration with European renewable gas markets.
Small Hydropower Plants (Small HPP)	48.5 MW (0.048 GW)	Limited growth due to environmental considerations and regulatory restrictions; the sector remains relatively stable with minor capacity additions.
Total Renewable Energy	10.934 GW (excluding large hydropower plants)	Overall growth of renewable capacity despite wartime conditions, mainly driven by distributed generation, private investments, and the strategic need for energy independence.

Source: Compiled based on [5, 18].

Bioenergy and small hydropower play a more specialized but still important role within the renewable energy system. Bioenergy projects are primarily oriented toward local heat and electricity generation and increasingly linked to the emerging biomethane sector, which may become an important export-oriented component of Ukraine's future energy strategy. At the same time, small hydropower remains a relatively stable but limited segment of the renewable sector due to environmental restrictions and regulatory requirements. Overall, the structure of renewable energy development suggests a gradual shift toward decentralized and diversified energy systems that strengthen the resilience of Ukraine's power sector.

The data presented in Table 2 illustrate the structural distribution of renewable energy capacity in Ukraine in 2025 and highlight the dominant role of solar energy within the national renewable energy mix. With an installed capacity exceeding 8 GW, solar power plants account for more than 74% of the total renewable energy capacity. This significant share reflects the rapid expansion of photovoltaic technologies over the past decade, supported by favorable natural conditions, relatively short construction periods, and the increasing spread of distributed solar installations in households and commercial facilities.

Table 2

Renewable Energy Capacity in Ukraine in 2025

Type of Renewable Energy	Installed Capacity (MW)	Installed Capacity (GW)	Share in Total RES (%)
Solar Energy (SPP)	8,112	8.112	74.2
Wind Energy (WPP)	2,311	2.311	21.1
Bioenergy (Biomass/Biogas)	463	0.463	4.2
Small Hydropower	48.5	0.048	0.4
Total RES	10,934.5	10.934	100

Source: Compiled based on [5, 18].

Wind energy represents the second largest segment of renewable generation, accounting for approximately 21% of the total installed renewable capacity. Although wind power plants possess significant technical potential in Ukraine, particularly in coastal and steppe regions, their development has been partially constrained in recent years by security risks and limited investment activity in regions affected by military operations. Nevertheless, wind energy continues to play an important role in diversifying the renewable energy portfolio and contributes to the long-term decarbonization of the electricity sector.

Bioenergy forms a smaller but strategically important component of Ukraine's renewable energy system, accounting for just over 4% of total installed renewable capacity. Unlike solar and wind power, bioenergy projects are often closely linked to local energy systems, agricultural production, and heat supply infrastructure. The development of biomass and biogas facilities also creates opportunities for the expansion of biomethane production, which is increasingly considered a promising direction for integrating Ukraine into the European renewable gas market.

Small hydropower plants account for less than 1% of total renewable energy capacity, reflecting the limited potential for large-scale expansion of this sector. Environmental constraints, regulatory requirements, and the relatively small number of suitable sites for new facilities restrict the growth of small hydropower projects. Overall, the structure of renewable energy capacity in Ukraine demonstrates a strong concentration in solar energy, while other renewable technologies play complementary roles in enhancing energy diversification and supporting the long-term resilience of the national energy system.

Table 3 summarizes the key strategic trends shaping the development of renewable energy in Ukraine and highlights the evolving role of different renewable technologies within the national energy system. Solar energy remains the primary driver of renewable energy expansion, particularly through the rapid growth of distributed photovoltaic systems. The increasing installation of rooftop solar panels by households, businesses, and municipal institutions reflects a broader shift toward decentralized generation and local energy resilience. At the same time, wind energy continues to serve as an important component of large-scale renewable electricity production, with ongoing modernization of infrastructure and the gradual development of hybrid systems combining wind generation with energy storage technologies.

Bioenergy and small hydropower complement the renewable energy structure by providing stable and predictable generation at the local level. Bioenergy development is increasingly linked with the production of biomethane and the use of agricultural residues, supporting both rural economic development and the principles of the circular economy. Small hydropower, while limited in expansion potential, contributes to system stability through reliable generation and modernization of existing facilities. Overall, the strategic trends identified in the table indicate a transition toward a more decentralized, flexible, and technologically integrated energy system, where renewable energy plays a central role in strengthening Ukraine's energy security and supporting its long-term integration with the European energy market.

Table 3

Strategic Trends in Renewable Energy Development in Ukraine

Type of Renewable Energy	Strategic Role in the Energy System	Development Trends and Policy Priorities
Solar Energy (SPP)	Key driver of renewable energy expansion and distributed generation.	Rapid growth of rooftop and distributed solar systems, integration with energy storage, and increasing role in strengthening local energy independence.
Wind Energy (WPP)	Important component of large-scale renewable electricity generation.	Expansion of wind projects in relatively secure regions, modernization of wind infrastructure, and development of hybrid energy systems.
Bioenergy (Biomass/Biogas)	Stable renewable source supporting local energy systems and heat supply.	Development of biomethane production, utilization of agricultural residues, and integration with circular economy approaches.
Small Hydropower	Supporting renewable generation with stable and predictable output.	Focus on modernization of existing facilities and compliance with environmental standards rather than large-scale expansion.
Renewable Energy System (Overall)	Strategic pillar of energy security and post-war reconstruction.	Transition toward decentralized generation, smart grids, hybrid plants with storage, and deeper integration with the European energy market.

Source: Compiled by the author based on own research.

Conclusions. The study confirms that the transformation of Ukraine's energy sector during the war is occurring within the broader context of the global energy transition, where decarbonization, energy security, and technological innovation are becoming interconnected priorities. The geopolitical shocks of the early 2020s have significantly accelerated the shift toward renewable energy sources and diversified energy systems. For Ukraine, this transformation has gained particular strategic significance, as the development of renewable energy is increasingly linked not only to climate policy but also to the resilience and stability of the national energy system under conditions of military conflict.

The analysis demonstrates that renewable energy sources are gradually strengthening their position within the structure of Ukraine's electricity generation. Solar energy has become the dominant renewable technology due to its relatively fast deployment, scalability, and suitability for distributed generation. At the same time, wind energy, bioenergy, and small hydropower contribute to diversification of the renewable energy portfolio, supporting the development of a more balanced and flexible energy system.

Another important finding of the study is the growing role of technological integration in modern energy systems. The development of energy storage technologies, digital grid management systems, and hybrid renewable power plants is becoming essential for maintaining system stability in networks with a high share of variable renewable generation. These technological solutions not only improve the operational flexibility of the energy system but also create new opportunities for integrating Ukraine's electricity market with the European energy space.

Overall, the transformation of Ukraine's energy sector during the war demonstrates that renewable energy can serve as a key driver of post-war reconstruction and long-term sustainable development. The combination of renewable energy expansion, decentralized generation, digital technologies, and the modernization of existing energy infrastructure may form the foundation for a more resilient, flexible, and environmentally sustainable energy system. In the long term, the development of green energy will play a crucial role in strengthening Ukraine's energy independence, supporting economic recovery, and facilitating deeper integration with the European energy market.

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RISK MANAGEMENT IN THE CONTEXT OF USING INFORMATION MODELING TECHNOLOGIES FOR CONSTRUCTION PROJECTS

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Abstract

Risks are inevitable in any construction project. To eliminate or mitigate their consequences, risk management methodology is applied in construction project management. In recent years, the likelihood of a risk event has increased in the architecture and construction industries due to increased structural complexity, the scope of construction work, and the use of new and complex construction methods. However, existing risk management practices have shown limited practical impact on the development of systematic risk management within construction projects. To address this issue, information modeling (IM) technologies play an important role in risk management at the design, construction, and maintenance stages of a construction project. Based on information technology, risk management can be integrated with modern IT processes for construction project management. Since the implementation of IM in risk management on construction projects remains limited, it is necessary to develop a IM implementation system to eliminate risks throughout the entire lifecycle of a construction project. This article examines the application of IM in risk management for construction projects at various stages of the project lifecycle.

The recommendations provided illustrate the use of risk management systems (RMS) in risk identification, risk response, and risk monitoring. Research shows that one of the most significant problems is the lack of a framework aligning RMS with risk management during project development and implementation. The development of such a framework encompasses a risk mitigation model, risk management cycles, and a flexible risk management structure across all stages of the construction project lifecycle.

Keywords: information modeling technologies (IMT), integration of IMT and risk management, construction.

Introduction

A construction project begins with the design phase, then goes through a lengthy construction phase, and finally an operational period lasting until complete depreciation and demolition. Consequently, various risks are present at all stages of the project's lifecycle. This means that, regardless of the type of activity, there is always a possibility of risky situations and impacts on the project, to varying degrees depending on the type of risk and the severity of the consequences. Risks manifest themselves in damage to structures, injuries or fatalities on-site, budget overruns, construction schedule delays, and so on.

In recent years, with the rapid development of urban infrastructure, risks have increased due to the increasing complexity and scale of projects and the use of innovative technologies and construction methods. Consequently, all participants in the investment and construction process must participate in risk management throughout the project's lifecycle to ensure its safe and sustainable completion. Risk management is a logical and systematic approach that includes a set of activities and processes to facilitate the exchange of information regarding the identification, analysis, assessment, and treatment of risks, as well as the reporting of achieved results.

The first and most important step in the risk management process is the early identification of potential risks. Based on this analysis, the likelihood of occurrence and the significance of the identified risks are then determined. To avoid serious accidents and improve the effectiveness of risk management in construction projects, various risk assessment methods are used in practice, such as fault tree analysis, decision trees, and neural networks (NN). These are divided into two categories: qualitative and quantitative risk analysis. However, it should be noted that these are primarily traditional methods, heavily dependent on the knowledge base and experience of managers.

In recent years, the development and application of construction information models has become one of the areas that will play a significant role in risk management during the design, construction, and operation

of facilities. IMTs are defined as "an object-oriented parametric three-dimensional model that digitally represents the physical, functional, and other characteristics of an object (or its individual parts) as a set of information-rich elements" [1]. A number of software applications are being used to support the practical use of IMTs, and IMT-related digital tools have also emerged to improve safety and risk management, such as replacing traditional 2D design methods with 3D modeling using automated verification tools built on IMTs to prevent traffic accidents on construction sites.

Currently, IMT platforms exist that can be applied to facility design for various purposes. However, integrating IMTs and risk management for construction projects remains a complex task.

Trends in the application of information modeling technologies for risk management in construction projects

The fundamental concept of risk mitigation is that the greatest opportunities for identifying and mitigating risks should be realized as early as possible during the design and planning stages, while residual risks should be managed during the construction and operation of the facility. Decision makers must establish an effective communication environment, clearly identify and analyze risks, implement measures to control them, and record and properly report the results. Typically, the project coordinator is responsible for monitoring, controlling, and managing the entire process, as well as ensuring effective operation throughout the project lifecycle. However, at each stage, responsibilities for risk management are identified.

Specifically, during the planning and design stage, the general designer is responsible for risk management and for collaborating with other project participants to identify all foreseeable risks that may arise during the lifecycle. During the construction phase, the general contractor is responsible for managing risks on the construction site to ensure the safe completion of the project within budget and on time. After the facility is handed over to the client (or operating organization) for daily maintenance and operational risk management.

However, there are some unresolved issues in the current risk management system for construction projects. For example, failure to identify potential project-related risks at the first stage of the risk management process can lead to new risks. Since the project goes through various stages and most participants complete their work during these stages, unidentified risks can lead to a "spillover effect" and the likelihood of risk events may increase.

Therefore, maintaining and applying a knowledge base acquired at each stage of the construction project, as well as collecting the necessary data are key prerequisites for successful risk management.

Another issue is that risk management in construction projects is a voluntary requirement. As projects progress, any common risks must be identified and addressed, and the relevant information documented. Sometimes this work can be ignored or forgotten. As a project moves from the designer to the contractor and then to the developer, large volumes of risk information can be lost if improperly recorded.

To overcome existing problems in traditional risk management, information modeling technologies have proven to be an effective way to facilitate early risk identification and assessment in design and construction through 3D visualization, 4D planning, and 5D cost estimating [3].

With the development of information modeling technologies, approaches to risk identification and analysis have been developed. The growing interest in the application of information modeling technologies in the risk management process is currently being explained by a number of factors.

First, the adopted general construction development strategy promotes the implementation of information modeling technologies in the construction industry. Secondly, risk management based on information modeling technologies allows construction companies to take advantage of the technology's technical advantages in early risk identification. For example, it becomes easier to identify errors and verify structures in 3D, and information modeling technologies, where parametric information is linked to objects, are convenient for any optimization and modifications [6].

Thirdly, large-scale construction projects, which involve a large number of multidisciplinary specialists, are complex to manage. Effective communication is always required for successful risk management. Information modeling technologies can

1) facilitate the creation of a communication environment that allows for an accurate understanding of the nature and needs of the project;

2) design, develop, and analyze the project;

3) manage the construction of the facility; and

4) manage the completed facility during its operation and decommissioning [5].

Integration of information modeling technology tools and the risk management process for construction projects

The integration of information modeling and the risk management process should proceed through several stages to ensure maximum alignment of information modeling capabilities with the risk management process.

1. The first stage involves defining the characteristics of project risk events, which are presented in the form of a corresponding catalog, indicating the risk code, risk type (e.g., external), risk impact area (e.g., legal, construction), the location of the risk event in the project life cycle (e.g., construction site, structures), and risk factors (e.g., insufficient project analysis or problems with utility networks). Next, a catalog of applicable risk management tools (RMT) is compiled, specifying the codes, the use of the RMT (e.g., for a construction site), a description (e.g., the use of a RMT in which geographic information system (GIS) tools are used in conjunction with software to determine the optimal location of a facility), the expected benefit (e.g., assessing an existing or potential facility in connection with a development program; savings on utility costs), information (e.g., site information—natural slope, road proximity, land use/coverage, land value, geological information), information source (e.g., owner, project en-

gineer), tools (e.g., software development, GIS software), and the model/results (e.g., an analytical model of the construction site). The catalogs can be expanded by adding both new risks and new RMT.

2. In the second stage, a risk analysis must be conducted to demonstrate the relationship between risks and the corresponding RMT by comparing the characteristics of each risk and the types of RMT. For this purpose, risk catalogs and IMTs are reviewed. Since each risk implies a specific information modeling technology application, a clear selection process is necessary to select the appropriate information modeling technology.

3. In the third stage, a final risk-IMT application catalog must be created. This catalog must specify the risk event, the risk impact area, the risk factor (e.g., incomplete project analysis), the simplified risk factor (e.g., verification), and the primary objective/sub-objective (e.g., conclusion/control). The relationships between risks and the characteristics of the IMTs used are determined based on the risk factors and the objectives of the IMT use [4]. Two types of classification of the IMTs used can be applied: based on the asset life cycle and the list of objectives for the IMT use.

Since not all IMTs are suitable for managing a particular risk, selection is necessary based on the risk characteristics and IMT. The main selection factors are the objectives for the IMT use, the asset life cycle, and the project elements. Targeted selection of IMTs is conducted using the risk-IMT catalog. Selection based on the asset life cycle (ALC) factor involves selecting IMTs based on the risk occurrence time. Selection based on the project element factor focuses on those elements where the risk arises.

Due to the complexity and variability of construction projects, risk distribution may vary, and adjustments to the IMT selection results may be required.

Despite some advances in risk management based on information modeling technologies, most practical efforts are focused on the design and construction phases of a project. Furthermore, it should be noted that due to technical limitations and the lack of human factors testing, most of these technologies are still at the conceptual stage and have not been widely used in real-world practice. Much of the development concerns new digital technologies for managing specific risks, such as predicting and preventing traffic accidents. Furthermore, traditional risk management methods and processes still play an important role in real-world projects. Clearly, future research will align information modeling technologies with traditional risk management methods in specific construction projects.

Overall, there remains a gap in the application of information modeling technologies for risk management on construction sites. Information modeling technologies will drive the development of the architectural, design, and survey industry (ADSI), making risk management more effective than it is today. Risk management will play a significant role when key construction project stakeholders begin to utilize these technologies in their daily work. However, little research currently focuses on how new and traditional risk management methods, activities, and processes can be integrated most effectively to make information modeling-based risk management more applicable in the ADS industry.

The information modeling technologies selected for each risk can be presented in tabular form (table). The application of information modeling technologies is distributed across all stages of the facility life cycle (FLC): the architectural and construction design (ACD) stage (including engineering surveys), the pre-construction stage (PC), the construction stage (C), the facility operation stage (O), and the facility disposal stage. For example, a technological risk may be identified at a construction site, and this risk is associated with specific information modeling technologies used to manage it—information modeling technologies 1 (Modeling Existing Conditions), information modeling technologies 3 (Visualization), and information modeling technologies 4 (Database Information Management)—which can be implemented to manage this risk throughout the project lifecycle.

While the matrix shows the appropriate information modeling technologies for risk management, it does not describe how to apply each information modeling technology in the risk management process. This requires the preparation of a separate guide with more detailed information on the use of information modeling technologies in risk management.

Risk management tasks for construction projects based on information modeling technologies

The proposed approach can be applied in two different scenarios. First, when risks or applicable IMTs are defined in the catalogs. Second, when risks or IMTs are not included in the catalogs and new risks and/or IMTs need to be added. The first scenario corresponds to a situation where the project planning team is satisfied that the catalogs are sufficient to characterize the project environment. In this scenario, the software can begin with risk exploration. If new risks and/or IMTs need to be added to the catalogs, the application must begin with data configuration.

Two user groups are defined. The first are risk and IMT experts, and the second are project clients and contractors. Since the adopted database structure is flexible enough to accommodate user modifications, new risks and IMTs can be added to the database in accordance with various project requirements and new IMTs. Risk and IMT experts can also review risk and IMT characteristics depending on their level of expertise. This includes database adjustments and an analysis of the IMT use objectives. The second group of users is more focused on applying the risk management process to the project.

If we consider the critical risks identified through classification (e.g., design changes, deficiencies in specifications and drawings, construction failures, and subcontractor performance), the goal of risk management will be primarily to reduce losses due to their impacts related to design, as well as to eliminate any construction conflicts, starting from the design stage, as they can lead to increased costs during construction.

Risk management measures should focus on the most important risks: poor workmanship and the need

to address it, equipment and material availability issues, safety/accidents, supplier/subcontractor problems due to low productivity, construction failures, inconsistencies between design and construction work, and exceptionally unfavorable climatic conditions.

This risk management approach depends largely on the experience and knowledge of specialists and the degree to which the problems to be solved are identified. There are limitations to the application of IMT if the company is a contractor and is guided by the client's requirements when applying IMT. In this situation, it is important for the contractor to maximize the use of IMT in risk management.

If the company operates at the operational stage of a facility, it is recommended to use IMT for the following purposes: infrastructure asset management: (1) record modeling, (2) disaster planning, (3) facilities monitoring and management, (4) infrastructure management, (5) building condition analysis, and (6) building maintenance planning.

Construction companies still lack sufficient information regarding the concept underlying the improved processes that IMT can offer. Another issue is that the decision to implement IMT depends on the scale of the construction project. Another important issue is that IMT implementation requires significant upfront costs. However, some employers would prefer to use more labor than invest in IMT.

Conclusion

Based on the research conducted in this article, it has been established that the link between project risks and the use of risk management tools remains insufficient. One potential direction for this research is to explore the methodology for using risk management tools in risk management. The implementation of risk management tools should not encounter common barriers such as a shortage of qualified experts or significant investment costs. Proposals are formulated for the application of existing and potential use of risk management tools.

A conceptual approach to integrating risk management tools into the risk management process is proposed. Within the overall risk management framework, a risk mitigation model is developed, linked to all stages of the investment and construction process: the architectural and construction design stage (including engineering surveys), the pre-construction stage, the construction stage, the facility operation stage, and the facility disposal stage.

A risk management cycle (identification, analysis, assessment, impact mitigation) is developed at each stage. This makes it possible to integrate cycle-based business processes into the risk management functions performed in structural units. At each stage of the project, the coordinator creates a flexible risk management service structure. This approach will expand the application of the IMT not only for risk identification and analysis, but also for decision-making.

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HISTORICAL AND ARCHEOLOGICAL SCIENCES

AN EXAMPLE OF LONG-LASTING STATEHOOD IN THE CAUCASUS - THE PLACE OF THE SHIRVANSHAHS' STATE IN THE HISTORY OF AZERBAIJAN

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Abstract

The Shirvanshahs State (861–1538) was one of the longest-lasting and strategically significant feudal states in the history of Azerbaijan. Its emergence took place against the backdrop of the weakening of the Arab Caliphate during the seventh to ninth centuries, the strengthening of local feudal forces, and the growing tendencies toward political autonomy. Haitham ibn Khalid of the Mazyadid dynasty was the first to adopt the title "Shirvanshah." Initially, the political center was Shirvan, and later the capital was transferred to Shamakhi. Despite northern incursions by the Rus', Kipchaks, and Mongols, as well as southern pressures and influence from the Seljuks, Timurids, and Aq Qoyunlu, the Shirvanshahs State succeeded in preserving its independence for an extended period.

The economic life of the Shirvanshahs State developed in close connection with its strategic location at the crossroads of major trade routes. The cities of Shamakhi and Baku evolved into principal economic centers, while silk, dye-producing plants, and minted metal coins were in demand in foreign markets. The Shirvanshahs also attached great importance to the advancement of culture. The literary achievements of prominent poets such as Khagani Shirvani, Falaki Shirvani, and Nizami Ganjavi reached their zenith during this period. The Shirvanshahs' court became a center of literary and scholarly gatherings. Architectural monuments, including mosques and mausoleums, reflect the political and economic strength as well as the cultural sophistication of the era.

The state was governed by three principal dynasties — the Mazyadid dynasty, the Kasranid dynasty, and the Derbendid dynasty. During each dynastic period, the Shirvanshahs maintained regional stability through diplomatic flexibility, defensive strategies, and centralized administration. Under the reigns of Ibrahim I of Shirvan and Khalilullah I, the state reached the peak of its political power, economic prosperity, and cultural flourishing.

In the sixteenth century, as a result of the campaigns of the Safavid Empire, the Shirvanshahs State ultimately fell. Nevertheless, the strategic and economic importance of the region remained intact. The activities and legacy of the Shirvanshahs constituted a significant stage in the formation of Azerbaijani statehood and culture, contributing substantially to the development of urban life, trade, literature, architecture, and scholarship. The administrative and diplomatic traditions they established form an essential historical foundation of modern Azerbaijani statehood.

Keywords: Shirvanshahs' state, title of Shirvanshah, domestic policy, foreign policy, culture.

İntroduction: The Shirvanshahs State occupies a significant place in the history of Azerbaijani statehood as one of its longest-lasting political entities. The study of its history is of considerable importance not only for Azerbaijan but also for understanding the broader political and cultural development of the Caucasus, the Sasanian world, and the Islamic-Turkic civilization. Formed from the seventh century onward, the Shirvanshahs State was situated along major trade routes due to its strategic geographical location and consequently became a focal point of various political events. Arabic and Persian medieval sources occupy a special place in the study of the Shirvanshahs' history. The works of Al-Tabari, Al-Baladhuri, Ibn al-Athir, Al-Masudi, and Yaqut al-Hamawi provide valuable information regarding the political history of the state. In addition, Tarikh al-Bab, the anonymous Hudud al-Alam, as well as Nizam al-Din Shami's Zafarnama and Hamdallah Mustawfi's Nuzhat al-Qulub are considered important sources on the political, economic, and social life of Shirvan.

Among Azerbaijani authors, Movses Kaghankatvatsi's History of the Country of Albania, the works of Abd al-Rashid al-Bakuvi, and Abbasgulu Agha Bakikhanov's Gulistan-i Iram play a crucial role in the study of Shirvan's ancient and medieval history. The literary heritage of thinkers such as Qatran Tabrizi, Khagani Shirvani, Falaki Shirvani, and Nizami Ganjavi also serves as an important source reflecting the sociocultural life of the period. The history of the Shirvanshahs likewise attracted the attention of European and Russian Orientalists. The studies of Bernhard Dorn and Vasily Minorsky made significant contributions to the examination of the state's political development. Among modern Azerbaijani historians, the works of Ziya Bunyadov, Sara Ashurbeyli, Naila Valikhanli, and Shahin Farzaliyev hold particular importance in the scholarly study of the Shirvanshahs. The Shirvanshahs period is studied not only through written sources but also through architectural monuments and numismatic materials. The Palace of the Shirvanshahs in Baku and the coins minted during the period constitute significant

historical evidence reflecting the political and economic power of the state.

Main text: Beginning in the second half of the ninth century, the weakening of the Arab Caliphate created favorable conditions for the emergence of independent feudal states in Azerbaijan. As a result of the decline of central authority, internal conflicts, and the expansion of liberation movements, provincial rulers effectively attained de facto independence. During this period, local dynasties came to power in various regions of Azerbaijan. From the ninth century onward, several feudal polities emerged, including the Marand principality, the Sajids, the Salarids, the Shaddadids, the Rawwadids, and the Shirvanshah Mazyadids.

One of the states that maintained its existence for a prolonged period was the Shirvanshahs' state, which functioned from 861 to 1538. Its territory encompassed the northern part of present-day Azerbaijan and partially extended into the lands of Dagestan, stretching eastward to the Caspian Sea and westward toward the direction of Ganja. The principal political and economic center of the state was the city of Shirvan, situated along the Shamakhi–Derbend trade route. There are various scholarly interpretations regarding the origin of the name Shirvan. It is noted that this toponym was mentioned in a Zoroastrian inscription dated to 224 BC. In medieval sources, Shirvan is described as comprising the eastern banks of the Kura River and forming part of Caucasian Albania [1, p. 18]. Vladimir Minorsky associated the name Shirvan with the word *"shir"* (lion), while other researchers have linked it to the name of ancient Sarmatian tribes. The term "Shirvanshah," derived from the title *"shah"* granted to provincial rulers during the Sasanian period, began to be used from the sixth century onward. In his work *Kitab al-Masalik wa al-Mamalik*, al-Istakhri notes that the Shirvanshahs were rulers who possessed extensive territories. Historical sources associate the origins of Shirvanshah authority with the reigns of the Sasanian rulers Ardashir I and Khosrow I Anushirvan [1, p. 39].

Historical evidence indicates that the Shirvan region had been inhabited by various tribes since ancient times. The migrations of the Huns, Sabirs, and Khazars into the area, as well as the resettlement policies implemented by the Sasanian rulers for the purpose of ensuring frontier security, significantly influenced the ethnic composition of the region. Although governance during this period was primarily exercised by the Sasanian authorities and later by Arab administrators, the majority of the population consisted of Turkic tribes.

Following the Arab campaigns in the Caucasus, administrative authority in Shirvan was entrusted to governors appointed by the Caliphate. According to al-Baladhuri, in 799 Yazid ibn Mazyad was appointed as the governor of Shirvan and Derbend. The Mazyadid dynasty, descended from him, consolidated its power in the region and laid the political foundations for the future Shirvanshahs' state. In the ninth century, the weakening of the Abbasid Caliphate—particularly as a result of the Khurramite movement—seriously undermined central authority and strengthened tendencies toward independence in the provinces. Consequently, in 861 the ruler of Shirvan, Heysam Mazyadid, took advantage of the prevailing political circumstances, declared himself independent, and adopted the title "Shirvanshah." Thus, the Shirvanshahs' state was formally established. Initially, the capital was the city of Shirvan, and from 918 onward it became Shamakhi.

At the time of its foundation, the state encompassed the territories between the Shabranchay and Gilgilchay rivers; however, its borders later expanded to include areas up to the Kura River, Derbend, Shaki, and the Caspian littoral [4, p. 47]. The cities of Shamakhi, Baku, and Derbend functioned as important political and commercial centers. Shamakhi played a significant role in international silk trade, becoming one of the principal economic hubs of the region. Shirvan silk and dye-producing plants were in high demand in foreign markets, and gold, silver, and copper coins were minted in the mints operating in Shabran.

Unlike other feudal states of Azerbaijan, the Shirvanshahs' state preserved its political existence for an extended period. Even during the Mongol invasions and the campaigns of the Seljuks and Timurids, it managed to maintain its sovereignty through a combination of diplomatic and military policies. Although the state was abolished in 1538 by the Safavid shah Tahmasib I, the title "Shirvanshah" continued to be used in subsequent periods [4, p. 115].

The Shirvanshahs' state, which occupied a significant place in the history of Azerbaijani statehood and existed for nearly a millennium, was governed by various dynasties. Although most scholars associate its rule primarily with three dynasties—the Mazyadids, the Kasranids, and the Derbendids—some authors, taking into account the early Shirvanshah rulers of Sasanian origin, identify four dynastic phases. In his work *History of Shirvan and Derbend*, Vladimir Minorsky notes that in the initial stage the Shirvanshahs were Persian-origin governors appointed by the Sasanian rulers [5, p. 62]. This view is also consistent with the accounts of medieval authors such as Ibn Khordadbeh, al-Baladhuri, and Fazlullah ibn Ruzbihan [1; 42].

Rashid al-Din attributed the Shirvanshahs to the lineage of the ancient rulers of Derbend and emphasized their prolonged rule [1, p. 53]. The tenth-century author al-Mas'udi stated that the Shirvanshahs descended from the Sasanian ruler Bahram Gur. B. Dorn supported this assertion, noting that the first governors appointed to Shirvan were relatives of Anushirvan. Qaffari and other authors likewise linked the genealogy of the Shirvanshahs to Khosrow I Anushirvan [1, p. 55].

These accounts are corroborated not only by written sources but also by Pahlavi inscriptions discovered in the fortresses of Derbend. The inscriptions indicate that the fortifications were constructed during the reign of Khosrow I to repel northern incursions [10, p. 10–12]. According to the calculations of Y. A. Pakhomov, these structures date to 568. Based on the sources, the earliest genealogy of the Shirvanshahs begins with Nasr ibn Jamasp, ruler of Derbend, and his son Surkhab. Thus, the early Shirvanshah rulers were of Sasanian origin; however, over time they assimilated with the local Turkic population and adapted to the socio-ethnic environment of the region.

Following the Arab campaigns in Azerbaijan, Shirvan came under the authority of the Caliphate, and its rulers were appointed by Arab governors. During the seventh and eighth centuries, the region was subjected to repeated incursions by Khazar and other Turkic tribes [1, p. 57]. Authors such as Hamza al-Isfahani, al-Baladhuri, and al-Mas'udi provide extensive accounts of these events.

From 861 onward, the Shirvanshahs' state was governed by three principal dynasties: the Mazyadids (861–1027), the Kasranids (1027–1382), and the Derbendids (1382–1538) [14, p. 40]. The Mazyadids, who belonged to the Arab Shaybani tribe, laid the foundations of political authority in Shirvan. During the reign of the Caliph Harun al-Rashid, Yazid ibn Mazyad, governor of the South Caucasus, played a significant military and political role in the region [4, p. 44]. His descendant, Heysam ibn Khalid, declared himself independent in 861 and adopted the title "Shirvanshah".

Under the Mazyadids, Shirvan's political position was consolidated, its territories were expanded, and a structured military-administrative system was established. During the reign of Heysam II, the state's defensive capacity was strengthened and economic measures were implemented. Nevertheless, in the tenth century, Rus incursions and attacks by northern tribes posed serious threats to the stability of the state.

The Kasranid dynasty, which came to power in 1027, is in fact regarded as a continuation of the Mazyadid lineage. With the accession of Shirvanshah Manuchihr ibn Yazid, Arabic names were abandoned and replaced with names of Sasanian origin, while the Persian language became widely used at court [5; 52;]. Z. Bunyadov, S. Ashurbeyli, and V. Minorsky interpret this development not as the emergence of a new dynasty, but rather as a transformation in titulature and cultural orientation. During the Kasranid period, the Shirvanshahs' state confronted the incursions of the Seljuks, the Rus, the Kipchaks, and the Mongols, while simultaneously experiencing growth in scholarship and urban life. Shamakhi and Baku developed into significant commercial centers. The rule of this dynasty continued until 1382.

In 1382, as a result of a popular uprising, the last Kasranid ruler, Hushang, was deposed, and power passed to Shaykh Ibrahim I, a representative of the Derbendid dynasty [4, p. 139]. As the thirty-fourth ruler of the Shirvanshahs, he succeeded in restoring political stability to the state. Although of Arab origin, the ruling family had by this time assimilated with the local population and undergone a process of Turkification. During the Derbendid period, the Shirvanshahs' state sought to preserve its independence through political struggle against the Golden Horde, the Aq Qoyunlu, and the Safavids. Ultimately, in 1538, the existence of the Shirvanshahs' state was brought to an end by the Safavid state.

The political crisis that unfolded within the Abbasid Caliphate in the second half of the ninth century significantly enhanced the autonomy of provincial rulers. The assassination of Caliph al-Mutawakkil in Baghdad in 861 further intensified instability within the Caliphate. Taking advantage of this situation, the ruler of Shirvan, Heysam ibn Khalid, achieved de facto independence and, for the first time, adopted the title "Shirvanshah". In *Jami' al-Duwal*, Munajjimbashi also refers to him as a Shirvan ruler belonging to the Mazyadid lineage. Following Heysam's death, his son Muhammad I (880–912) ascended the throne. He devoted particular attention to strengthening the state's defenses, ordering the construction of food depots to safeguard the northern frontiers and organizing the maintenance of the *ghazis*. As part of this defensive policy, several villages were granted as *waqf* endowments to the *ghazis* of Derbend [1, p. 95].

During the reign of his successor, Ali ibn Heysam (913–917), Shirvan faced both internal political difficulties and external threats. In this period, Abu'l-Saj Yusuf, ruler of the Sajid state, imposed vassal dependence upon the Shirvanshahs. In 913–914, a Rus expedition advanced through the Caspian Sea toward Absheron and Baku, inflicting severe damage upon the country. According to al-Mas'udi, the Rus entered the region with 500 ships and carried out extensive devastation [1, p. 96]. The absence of a naval fleet resulted in heavy losses for the Shirvanshahs.

After these events, power passed to Abu Tahir Yazid ibn Muhammad (917–948). He unified Shirvan and Layzan, expanding the state's territory from the Kura River to Derbend. One of Abu Tahir's significant domestic measures was the transfer of the capital to the more strategically secure city of Shamakhi, which was renamed Yazidiyya in his honor. During Abu Tahir's reign, Shirvan maintained political relations with the Sajids and later the Salarids, preserving its internal autonomy in exchange for the payment of tribute. The struggle for control over Derbend became one of the principal directions of the state's foreign policy. The recurrent wars and peace agreements concerning Derbend at various times underscored the strategic importance of the region [1, p. 102].

During the reigns of Muhammad ibn Yazid and Ahmad ibn Muhammad, who succeeded Abu Tahir, the struggle for control over Derbend and conflicts with neighboring feudal principalities continued. Although the Shirvanshahs at times paid tribute to the Salarids, they retained internal administrative authority in their own hands. Toward the end of the tenth century, Muhammad ibn Ahmad expanded Shirvan's territories, establishing control over Gabala, Barda, and Shabran.

The reign of Yazid ibn Ahmad (991–1027), who came to power after him, was largely characterized by continuous warfare over Derbend. During this period, the restoration of fortresses and defensive structures, as well as the consolidation of borders, constituted central elements of state policy [1, p. 108]. The struggle for control over the Derbend region persisted for an extended time, and the city changed hands several times between rival forces. Under the Mazyadids, the policy of the Shirvanshahs was primarily directed toward countering threats from the north. By paying tribute to the Sajids and the Salarids, the state preserved its internal autonomy while strengthening its defensive system through fortresses and frontier fortifications. The en-

forcement of strict succession traditions within the ruling family, aimed at preventing dynastic conflicts, was also characteristic of this period [1, p. 114].

The Mazyadids, who ruled from 861 to 1027, constituted the first Muslim dynasty of the Shirvanshahs. Although the state did not always possess full political sovereignty, it maintained its internal autonomy for a prolonged period and pursued a defensive policy against northern incursions. Despite the economic strain caused by nomadic invasions and continuous warfare, Shirvan succeeded in preserving its regional political position [70].

The medieval history of Azerbaijan is distinguished by its rich traditions of statehood, in which the Kasranid dynasty played a significant role. Ruling Shirvan from 1027 to 1382, this dynasty was instrumental in maintaining political stability and promoting cultural development. During this period, cities such as Shamakhi, Baku, and Derbend experienced growth, trade routes expanded, and a revival in science and literature was observed.

The ascension of the Kasranids coincided with the decline of the Arab Caliphate and the formation of independent feudal states in the region. Shirvan fell within the spheres of interest of the Seljuks, the Kingdom of Georgia, the Rus principalities, and later the Khwarezmshahs and Mongols. In this complex context, the foreign policy of the Shirvanshahs played a decisive role in ensuring the long-term survival of the state.

The dynasty was founded in 1027, a date considered the beginning of a new political phase following the Mazyadids. Although the Kasranids originated from the Arab Yazidi lineage, they gradually integrated into the local environment and adopted Turkic and Persian cultural influences. They managed to preserve a degree of autonomy by maintaining diplomatic balance in their relations with the Seljuks, the Mongols, and the Hulaguids. Historians identify Kasran ibn Yazid as the founder of the dynasty. The epithet “Kasran” was originally attributed to Yazid ibn Ahmad and later came to represent the dynasty as a whole. Some scholars link this name to the Sasanian royal title “Kisra,” suggesting a claim to political legitimacy.

The early Kasranid rulers pursued policies aimed at consolidating internal stability, employing both diplomatic and military methods to bring tribal leaders under central authority. Loyal governors were appointed in the provinces, and the tax system was centralized. From the eleventh to the thirteenth centuries, Shirvan functioned as a buffer zone between major empires. This position both exposed the state to external threats and provided opportunities for diplomatic maneuvering [10, p. 99]. During this period, the Seljuks, the Georgians, and later the Ilkhanids sought to exert control over Shirvan.

The principal cities of Shirvan—Shamakhi, Baku, Barda, Gabala, and others—functioned as political, economic, and religious centers. Within the framework of the feudal administrative system, governors (*valis*) were appointed to the provinces, while the central authority maintained oversight. The mountainous terrain and fortified strongholds, such as Shamakhi, Gulustan, and Bash Shirvan, provided a strategic defensive advantage. The ethnic and tribal diversity of the region necessitated flexible governance policies [7, p. 118;]. The Kasranids pursued strategies of alliance and kinship with tribal leaders, resorting to military measures in cases of disobedience. In mountainous areas like Shaki and Gabala, a policy of relative autonomy was implemented.

During the Kasranid period, governance was based on a feudal monarchical model. The “Shirvanshah” held supreme authority, while positions such as vizier, sadr, emir, qazi, and *amil* formed the core of the state apparatus. Both Sharia law and local customary law were applied [12, p. 148]. This system balanced centralization with feudal autonomy. The reign of Manuchihr I (1027–1034) was marked by the maintenance of internal stability. In 1032, a Rus invasion inflicted economic damage, yet political independence was preserved. During the periods of Abu Mansur and Qubad ibn Yazid, policies of defense and diplomatic balance continued to be emphasized.

During the reign of Farrukhzad I, Shirvan faced military challenges from Arran and Georgian forces, negotiated peace treaties, and simultaneously pursued a balanced policy under the influence of the Seljuks. In 1066–1067, Oghuz incursions posed a serious threat to the state, but the situation was stabilized through a combination of diplomatic and military measures. Under Manuchihr III, Shirvan was nominally subordinate to the Seljuks but sought to maintain de facto independence. The regional dynamics shifted following the strengthening of Georgia after the Battle of Didgori in 1121. During the reign of Akhsitan I (1160–1197), central authority was consolidated. After the earthquake of 1192, the capital was relocated to Baku, which proved strategically significant for both defense and trade [12, p. 88]. International commerce expanded through the port of Baku, and even a naval fleet was established in the Caspian Sea [10, p. 115].

In the thirteenth century, the Mongol invasions altered the political landscape of the region. As noted by Sara Ashurbeyli, although the Shirvanshahs came under Mongol influence, they were able to preserve their internal autonomy. During the reigns of Akhsitan III and Keykavus I, diplomatic flexibility and administrative reforms contributed to the maintenance of stability. Under Keyqubad I and Kavus I, Shirvan maintained balanced relations with the Jalairids and other Turkic dynasties, while the port of Baku became a central pillar of the state’s economic strength.

The reign of Hushang I (1372–1382) was complicated by the campaigns of Timur. Although Shirvan was unable to offer open resistance, it preserved its formal independence through diplomatic submission. Despite economic weakening, the state institutions remained largely intact. Overall, during the Kasranid period, the Shirvanshahs’ state was constantly within the sphere of interest of regional powers due to its strategic location. Foreign policy focused on preserving independence and maintaining a diplomatic balance. In dealings with the Seljuks, Atabegs, Georgians, Mongols, Jalairids, and ultimately the Timurids, Shirvan pursued a pragmatic and flexible course.

Thus, over more than three centuries, the Kasranid dynasty succeeded in maintaining political stability, preserving statehood traditions, and sustaining Shirvan's regional role. Information on other dynasties that ruled the Shirvanshahs' state has already been provided. In this subsection, the rule of the Derbendid dynasty and the factors leading to the state's decline are examined. According to V. Minorsky, Shaykh Ibrahim was the first representative of the Derbendid line, a branch of the Mazyadid dynasty. According to tradition, his father, Sultan Muhammad ibn Keyqubad, fled to Shaki to escape Hushang's oppression and died there. Shaykh Ibrahim spent his youth in this simple, local setting. Ruling from 1382 to 1417, Shaykh Ibrahim was the thirty-fourth Shirvanshah. The Derbendis had assimilated with the local population and undergone Turkification.

By the late fourteenth century, Shirvan faced threats from Timur in the south and Tokhtamysh in the north. Shaykh Ibrahim assessed the situation prudently and submitted to Timur in 1386, thereby saving the country from destruction. He had sermons delivered in Timur's name, minted coins bearing his authority, and presented valuable gifts in person. According to a well-known account, presenting himself as the "ninth servant" earned Timur's favor [1, p. 294]. As a result, Shaykh Ibrahim was reappointed as ruler and was granted additional territories.

During this period, coins were minted in Baku, Shamakhi, and Derbend in the names of Timur and, occasionally, Tokhtamysh [9, p. 84–86]. Thanks to Shaykh Ibrahim's skillful diplomatic maneuvering, Shirvan was spared from devastation. After Timur's victory over Tokhtamysh in 1395, the northern threat diminished [2, p. 47]. Although warfare caused economic damage, Shaykh Ibrahim was able to restore the country. Following Timur's death in 1405, Shaykh Ibrahim sought to consolidate Azerbaijani territories by exploiting the internal conflicts among the Timurids. In 1406, he temporarily occupied Tabriz, but withdrew upon the arrival of Jalairid Sultan Ahmad [1, p. 300]. Relations with Qara Yusuf deteriorated, and in 1412, Shaykh Ibrahim was defeated and captured in a battle along the Kura River [1, p. 315]. He was later released upon payment of a ransom and resumed rule over Shirvan. Shaykh Ibrahim died in 1417, concluding a 35-year reign [2, p. 48]. His successor, Khalilullah I (1417–1465), presided over a period of political stability and cultural flourishing in Shirvan. He formed an alliance with Shah Rukh, Timur's son [1, p. 305], and achieved victory against Iskandar in 1429. Iskandar's 1434 campaign was also rendered ineffective due to Shah Rukh's intervention.

During the reign of Khalilullah I, the port of Baku experienced significant development, and trade expanded via the Caspian Sea to the Volga region and the Grand Duchy of Moscow [1, p. 301]. Diplomatic relations were established: in 1465, Hasan Bey was sent to Moscow, and in 1466, Ivan III dispatched an envoy in return. These exchanges strengthened economic ties. Khalilullah I's period is also remembered for an architectural flourishing. The Shirvanshahs' palace complex in Baku, along with mosques and mausoleums, became enduring symbols of his reign. He died in 1465 [1, p. 310–311]. He was succeeded by Farrukh Yasar, whose reign was marked by continuous warfare and political challenges. The rise of Uzun Hasan altered the regional balance of power [6, p. 128]. Farrukh Yasar sought to establish relations with Ottoman Sultan Mehmed the Conqueror and maintained diplomatic contacts with Moscow. In 1468, he was involved in the events surrounding Abu Said's defeat [1, p. 301–303].

Between 1471 and 1475, wars with the Aq Qoyunlu forced him temporarily into submission to Uzun Hasan. Later, during the reign of Sultan Yaqub, relations were reinforced through marital alliances. Nevertheless, the growing power of the Aq Qoyunlu and, subsequently, the Safavids undermined the Shirvanshahs' state, setting the stage for its eventual decline and collapse.

Azerbaijan's ancient and medieval history is distinguished by its rich statehood traditions. The Shirvanshahs' state, which existed from the mid-ninth century to the early sixteenth century, played a crucial role in the political, economic, and cultural life of the region and served as a successful example of independent rule by local dynasties. The weakening of the Arab Caliphate, the strengthening of local feudal powers, and growing tendencies toward political autonomy created favorable conditions for the emergence of statehood in Shirvan. Rulers from the Mazyadid lineage, descending from Yazid ibn Mazyad, adopted the title "Shirvanshah," reflecting both their claim to independence and the continuation of Sasanian traditions.

The significance of the Shirvanshahs' state is evident in several key areas. Politically, they maintained both allied and rival relations with powerful states such as the Seljuks, Eldiguzids, the Golden Horde, and the Timurids, preserving their independence over a long period and contributing to the development of unified governance traditions. During the reigns of Ibrahim I (1382–1417) and Khalilullah I (1417–1465), the state's power and economic prosperity increased significantly. Economically, Shirvan occupied a strategic position at the intersection of trade routes, establishing international connections via both the Silk Road and the Caspian Sea. Shirvanshah cities—initially Shamakhi and later Baku—developed as economic centers, fostering crafts, agriculture, and commerce. The port of Baku played a vital role in the Caspian region, with oil, salt, carpets, silk, and agricultural products serving as principal export goods.

In the cultural sphere, the Shirvanshahs' state provided extensive opportunities for the development of Azerbaijani literature and culture. Prominent poets such as Khagani Shirvani, Falaki Shirvani, and Nizami Ganjavi were active in this environment, and the Shirvan court became a center for literary and cultural assemblies as well as scholarly discussions. The architectural heritage—including the Shirvanshahs' palace complex, mosques, and mausoleums—has been preserved to the present day. Attention to science and education fostered the study of mathematics, astronomy, medicine, and philosophy, with the Sufi sheikh Seyyid Yahya Bakuvi playing a significant role in these fields.

The Shirvanshahs maintained their political existence for an extended period, preserving independence despite pressures from various empires through diplomatic skill and defensive measures. In the early sixteenth century, Shirvan was incorporated into the Safavid state as a result of Shah Ismail's campaigns, yet the region continued to remain an important strategic and economic center. The economic, political, and cultural activities of the Shirvanshahs marked a crucial stage in the formation of Azerbaijani statehood and cultural traditions, contributing to urban culture, craftsmanship, trade, architecture, literature, and the development of science [13, p. 192]. The cultural environment and governance traditions they established remain one of the historical and spiritual foundations of contemporary Azerbaijani statehood.

Conclusion: The Shirvanshahs' state should be regarded as one of the longest-lasting and most influential political entities in the history of Azerbaijani statehood. Its centuries-long existence was not accidental; the establishment and development of the state contributed to the preservation of the people's statehood traditions, the formation of national identity, and the enrichment of cultural life. At the same time, the Shirvanshahs' presence helped maintain a certain degree of political stability in the South Caucasus. Studying the historical trajectory of this state is of great significance for Azerbaijani historiography, as it provides valuable lessons in governance, diplomacy, and the development of cultural life.

During the rule of the Mazyadid dynasty, the political foundations of the state were laid. Key features of this period included the establishment of centralized authority, the maintenance of internal stability, and the preservation of territorial integrity. In foreign policy, efforts were made to protect the state's independence, with resilient strategies developed to counter the influence of powerful regional states. The greatest historical achievement of the Mazyadids was the preservation of independent statehood traditions in Azerbaijan's northern territories. The experience gained during this period played a fundamental role in shaping the political activities of the Shirvanshahs in later centuries.

Under the Kesranid dynasty, the Shirvanshahs' state reached the peak of its political power. The country experienced economic revival, urban centers expanded, and trade networks flourished. Shirvan's strategic location at the crossroads of important international trade routes was a key factor in its economic development. Cities such as Baku, Shamakhi, and Gabala became major commercial hubs, serving as the economic center of the region. The Kesranid period also saw notable cultural advancement. The Shirvanshahs' Palace Complex, a masterpiece of architecture from this era, has been preserved as a brilliant example of Azerbaijani cultural heritage. Significant achievements were also made in literature and science, with classical representatives of Azerbaijani literature active during this time. This indicates that cultural life in the state flourished not only at the court but across the broader society.

During the rule of the Derbendis, however, the state began to weaken. The main causes of this decline included internal conflicts, feudal fragmentation, increasing external invasions, and the weakening of central authority. The economy suffered, trade routes became insecure, and agricultural productivity declined. During this period, the process of the state's collapse accelerated. Nevertheless, the statehood traditions of the Shirvanshahs were not entirely lost. Their administrative structures, diplomatic practices, and cultural legacy continued to be remembered by the people and exerted a significant influence on the functioning of subsequent Azerbaijani states.

The most significant legacy of the Shirvanshahs lies in the preservation of Azerbaijani statehood traditions. For centuries, they struggled to maintain a centralized authority, employed flexible diplomacy to counter the pressures of neighboring states, and endeavored to safeguard the country's internal stability. This experience demonstrates that a strong central government, national unity, and diplomatic agility are of vital importance for Azerbaijan's political independence. The governance practices of the Shirvanshahs left a profound impact not only on the history of Azerbaijan but also on the political culture of the broader Caucasus region.

The economic policies of the Shirvanshahs played a crucial role in strengthening the country. Azerbaijan's advantageous geographic position—situated at the intersection of international trade routes—enhanced the Shirvanshahs' economic standing. International trade expanded through the port of Baku, and Shamakhi silk gained recognition in numerous markets worldwide. The development of irrigation systems in agriculture increased productivity, while the growth of craftsmanship played a significant role in the socio-economic life of urban centers. This economic experience laid a solid foundation for the future development of the Azerbaijani people.

The Shirvanshah state stands out as one of the long-lasting and influential political entities in Azerbaijani history. For centuries, they contended for centralized authority, strived to maintain internal stability, and conducted flexible diplomacy against pressures from neighboring powers. This historical experience underscores that a strong central government, national unity, and diplomatic adaptability are indispensable for ensuring Azerbaijan's political independence. The economic policies of the Shirvanshahs played a crucial role in the development of the country. Azerbaijan's strategic geographic location—situated at the crossroads of international trade routes—strengthened the Shirvanshahs' economic position. International trade expanded through the port of Baku, and Shamakhi silk gained recognition in numerous markets worldwide. Irrigation systems were implemented in agriculture, leading to increased productivity, while the development of craftsmanship significantly contributed to the socio-economic life of urban centers. This economic experience laid a solid foundation for the future development of the Azerbaijani people.

In the cultural sphere, the era of the Shirvanshahs marked a period of revival in Azerbaijani history. The Shirvanshahs Palace complex in Baku, architectural monuments in Shamakhi, Gabala, and other cities, as

well as mosques and religious sites, reflect the high cultural standards of this period. In literature, the formation of classical traditions, along with the advancement of science and education, exemplifies the Shirvanshahs' support for culture. Poets such as Khagani Shirvani, Falaki Shirvani, and Nizami Ganjavi flourished in this environment, and literature and the arts thrived within the court and urban life. In the field of science, scholars contributed to mathematics, astronomy, medicine, and philosophy, while the Sufi sheikh Seyid Yahya Bakuvi made valuable contributions to medieval Azerbaijani philosophy through his philosophical and religious works.

The decline of the Shirvanshahs demonstrates that internal stability, a strong central authority, and national unity are essential for the longevity of a state. Feudal fragmentation, political intrigues, and foreign interventions led to the weakening and eventual collapse of the state. Nevertheless, the Shirvanshahs' political experience, economic achievements, and cultural heritage remain an integral part of the statehood traditions of the Republic of Azerbaijan. The values they established played a significant role in shaping national identity, cultural heritage, and political consciousness.

Thus, the Shirvanshah state influenced not only Azerbaijan but the entire Caucasus region in terms of political, economic, and cultural development. Their traditions of governance have been preserved over centuries and continue to resonate in the present day. The activities of the Shirvanshahs once again demonstrate that national unity, strong statehood traditions, and cultural development are foundational pillars of a nation's independence. "The legacy of the Shirvanshahs has left a profound imprint on the historical memory of the Azerbaijani people, serving as both a political and cultural lesson for future generations."

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ОСОБЛИВОСТІ ТАКТИКИ ПАРТИЗАНСЬКИХ (ПОВСТАНСЬКИХ) ФОРМУВАНЬ У ВОЄННИХ КОНФЛІКТАХ 1990-х РОКІВ – НА ПОЧАТКУ XXI ст.

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THE PECULIARITIES OF TACTICS GUERRILLAS (INSURGENTS) FORMATIONS IN MILITARY CONFLICTS OF THE 1990s AND EARLY 21st CENTURY

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Анотація

У статті *розкрито* особливості тактичних дій партизансько-повстанських формувань у воєнних конфліктах 1990-х – початку XXI ст. Зокрема *розглянуто* тактику повстанських формувань проти регулярних російських частин і підрозділів в обох Чеченських війнах (1994–1996 рр. і 1999–2000 рр.), тактику партизанських дій в Афганістані у 2001–2011 рр. і тактику іракських повстанців проти Коаліційних сил у 2003–2011 рр. *Зроблено* висновки щодо спільного у діях партизансько-повстанських сил у зазначених воєнних конфліктах, *з'ясовано* їх тактику, *виявлено* сильні та слабкі сторони, *встановлено* способи партизанських (повстанських) дій, які мають свої особливості, що залежать від фізико-географічних умов району дій (операції) та оперативної обстановки, змісту завдань, які виконують партизанські (повстанські) формування, наявних сил і засобів, рівня забезпечення їх дій, бойового досвіду особового складу і командних кадрів та інших чинників. Водночас основну увагу приділяли підготовці фахівців з цієї діяльності під час організації партизанської боротьби на тимчасово окупованій території.

Abstract

The article reveals the peculiarities of the tactical actions of guerrilla and insurgent formations in military conflicts of the 1990s and the early 21st century. Specifically, the examines the tactics of rebel formations against the regular Russian units and subunits in both Chechen Wars (1994–1996 and 1999–2000), the tactics of guerrilla actions in Afghanistan from 2001–2011, and the tactics of Iraqi insurgents against Coalition Forces from 2003–2011. Conclusions are drawn regarding joint actions of guerrilla and insurgent forces in the specified military conflicts, their tactics are clarified, their strengths and weaknesses are identified, and the methods of guerrilla (insurgent) actions. These methods possess specific features that depend on: the physic-geographical conditions of the area of operations; the operational situation; the nature of the tasks performed by the guerrilla (insurgent) formations; the available forces and means; the level of support for their actions; the combat experience of personnel and command staff; as well as the counter-diversionary measures of regular troops to search for and destroy guerrillas (insurgents) in their areas of operation, and other factors. At the same time, primary attention was paid to the training of specialists in this field during the organization of guerrilla warfare in temporarily occupied territory.

Ключові слова: партизанська (повстанська) боротьба, партизанська тактика, партизан-ський (повстанський) рух, партизанські (повстанські) формування, Коаліційні війська.

Keywords: guerrilla (insurgent) struggle, guerrilla tactics, guerrilla (insurgent) movement, guerrilla (insurgent) formations, Coalition Forces.

У попередній статті нами розглянуто особливості тактики партизансько-повстанських формувань у повоєнних конфліктах (1945–1989 рр.). У статті зазначено, що переважна більшість з них мала внутрішньодержавний, громадянський характер. А іррегулярні сили, які залучалися у цих конфліктах ефективно використовували принципи ведення "малої" або "народної" війни, до чого, як правило, протидіюча сторона була практично не готова [16].

Значні геополітичні зміни, що відбувалися в цей період, призвели до воєнних конфліктів різного масштабу, і суттєво вплинули на розвиток збройного

протиборства. Проте, зазначимо, що конфліктні ситуації все частіше переростають у збройний конфлікт. На зміну конвенційним або тотальним війнам між державами та коаліціями держав приходять війни нового концептуального типу, які ведуть між собою соціально-політичні недержавні угруповання. Їх ефективність продемонструвала боротьба палестинців, які у такий спосіб досягли створення власної Палестинської держави, чого не змогли зробити ні Організація Об'єднаних Націй (ООН), ні півстоліття війн регулярних арабських армій проти Ізраїлю.

З розпадом СРСР Чечено-Інгушська АРСР розпалась на дві незалежні республіки. У липні 1991 р. на Загальнонаціональному конгресі чеченського народу було заявлено, що Чеченська Республіка не входить до складу СРСР і РРФСР. У вересні 1991 р. з'їзд депутатів Інгушетії проголосив Інгуську Республіку у складі РРФСР. 27 жовтня 1991 р. у Чеченській Республіці було засновано пост президента, який зайняв генерал-майор Д. Дудаєв, колишній офіцер радянської армії. Верховна Рада Росії не визнала ці вибори, вважаючи їх незаконними. Деякі чеченські лідери склали Д. Дудаєву опозицію. Особливо гостро їх протиборство проявилося навесні 1993 р., коли вірні президенту Д. Дудаєву війська у Грозному із застосуванням зброї придушили виступ його противників. У подальшому події в республіці розвивалися дуже стрімко, привівши її населення до громадянської війни з одночасним різким погіршенням відносин з Росією [5, с.738-739].

Розглянемо **тактику чеченських повстанців** у боротьбі з російськими частинами і підрозділами у **1994–1996 рр.** і **1999–2000 рр.** У листопаді 1994 р. була зроблена невдала спроба штурму Грозного антидудаєвською опозицією, яку підтримував федеральний центр. 30 листопада 1994 р. президент Російської Федерації Б. Єльцин у своєму указі "О некоторых мерах по укреплению правопорядка на Северном Кавказе" (наведено мовою оригіналу – *прим. авт.*) зажадав від усіх осіб, які незаконно мають зброю, здати її протягом 15 днів російським правоохоронним органам. У Чечні ці вимоги проігнорували. 11 грудня 1994 р. Б. Єльцин прийняв рішення про початок на території республіки загальновійськової операції російських федеральних військ. Так Російська Федерація була втягнута в затяжну кровопролитну війну на Північному Кавказі.

Після двомісячного штурму федеральні війська захопили Грозний (за даними чеченських джерел, при штурмі міста загинуло до 30 тис. мирних жителів). За три перших місяці проведення операції російські війська взяли під свій контроль північну та більшу частину центральної частини Чеченської Республіки. Після відносно спокійного березня, протягом якого провели переговори з Д. Дудаєвим, а російські війська вивели з Грозного і замінили на підрозділи міліції, знову почалися бойові дії. До кінця березня федеральні війська захопили три великі та стратегічно важливі міста – Аргун, Гудермес і Шалі. Чеченських повстанців витіснили у південні, гірські райони республіки. Це змусило їх змінити тактику ведення військових операцій. Починаючи з квітня 1995 р. повстанці відмовилися від війни суцільним фронтом, розділилися на багато невеликих загонів і розпочали партизанську війну.

По мірі просування федеральних військ на південь повстанські загони почали "просочуватися" на уже відбиті у них території. Під покровом темряви вони нападали на гарнізони, комендатури і блокпости. Крім того, різко зросла кількість терористичних операцій, скерованих проти федеральних солдатів і чеченських лідерів, лояльних до Росії. У південних районах республіки федеральні війська наштовхнулися на запеклий і добре спланований спротив. Гірські райони і масиви густо вкриті деревами і кущами ("зеленка"), які розпускалися навесні, чеченські повстанці уміло використовували як природне укриття [5, с.739].

Досвід обох чеченських кампаній засвідчив, що повстанські формування створювалися зазвичай за територіальним або родовим принципом. Їх чисельність і організаційна структура не була постійною і змінювалася залежно від виконуваних завдань, умов обстановки, наявності сил і засобів. Очолював формування командир (командувач) зі своїм штабом. Їм нерідко надавали допомогу та підтримку закордонні рухи, общини й організації [5, с.742].

Під керівництвом командира (командувача) було 1–2 угруповання, кожне з яких налічувало 500 і більше осіб. З них одне угруповання було бойовим і призначалося для безпосереднього ведення бойових дій. Інше – резервне, для поповнення втрат, нарощування зусиль і плавної заміни бійців, що воюють, яку проводили через 5–7 днів.

Угруповання складалося з кількох загонів, в яких налічувалося по 100–150 бійців. Керували загонами польові командири. Загін зазвичай ділився на три групи. Найчисельніша (80–100 осіб) і підготовлена, добре оснащена центральна група (бойова), завжди знаходилася з командиром у готовності до бою і не мала постійного місця дислокації. Друга (спеціальна) група чисельністю 20–30 осіб дислокувалася у населеному пункті, підпорядковувалася тільки командиру загону. Члени групи були глибоко законспіровані та займалися повсякденною діяльністю. Проте всі вони пройшли підготовку у спеціальних навчальних центрах (у т. ч. і за кордоном) і спеціалізувалися на диверсійно-розвідувальній діяльності, снайперській стрільбі, мінуванні об'єктів і комунікацій. Повстанці третьої групи (20–30 осіб) проживали в населених пунктах. За наказом командира вони прибували до загону, виконували у його складі конкретне бойове завдання і поверталися додому. Вони могли діяти і самостійно на рішення командира. Водночас, вони виконували допоміжні функції по збору інформації, обладнанню баз і позицій, доставлянні матеріальних засобів до місць бойових дій [11, с.18].

Ядром загону була бойова група, яка складалася з трьох взводів (20–25 осіб) у складі трьох відділень кожний. Крім того, кожна бойова група на озброєнні могла мати: кулемет ДШК чи НСВ – 1–2, міномети – 1–2, ПТРК – 1–2, переносні РСЗВ чи безвіткатні гармати – 1, зенітні установки – 1–2, ПЗРК – 2–3. Були

випадки, коли створювали формування, які мали організаційну структуру на зразок регулярної армії – батальйон, рота, взвод. Об'єднання повстанських формувань у великі угруповання відбувалося для захоплення стратегічно важливих ділянок місцевості і населених пунктів (до 3000 осіб) [10, с.21].

Загони в основному комплектували добре підготовленим особовим складом різних вікових категорій (20–50 років) за принципом добровільності, проте й не виключали примусової мобілізації чоловічого населення.

Для здійснення військової підготовки повстанців були створені навчальні центри (школи). Насамперед це обумовлено тим, що в умовах партизанської війни їх особовому складу необхідні були особливі знання, уміння та навички.

Основними дисциплінами, які обов'язково вивчали повстанців під час підготовки були: тактика, вогнева підготовка, диверсійна (підривна) справа, методи здійснення терактів, зв'язок, топографія, способи пересування і маскування, способи виживання у польових умовах, надання першої медичної допомоги. Приділяли увагу й навчанню пропагандистської роботи з цивільним населенням.

Водночас керівництво повстанців особливу увагу приділяло створенню інфраструктури для організацій і ведення збройної боротьби – створювалася система зв'язку, мережа базових районів, перевалочних баз, опорних пунктів, складів і зон для розміщення керівництва та всебічного забезпечення діючих бойових груп і загонів. Базові райони – значні за площею території у важкодоступній гірській місцевості, добре обладнані в інженерному відношенні та мають розвинену мережу оборонних споруд і загороджень. Зазвичай їх прикривали засобами протиповітряної оборони (ППО). Основні елементи базових районів: штаб, навчальний центр, склади, ремонтні майстерні, шпиталь, житлові будівлі (приміщення), укриття. Там само розміщувалися гарнізони для їх обслуговування, охорони та оборони.

Бази являли собою невеликі за площею об'єкти, призначені для розміщення збройного формування (угруповання), зберігання їх зброї та майна. Перевалочні бази і пункти утворювали проміжні місця постачання повстанців. Тут здійснювали перевантаження зброї, боєприпасів, матеріальних засобів з транспорту, що надійшов з інших районів, на транспорт партизанів. У південно-східних і південно-західних районах Чечні, за даними розвідки, було обладнано понад 60 баз і складів із запасами зброї, боєприпасів, медикаментів та продовольства [11, с.22-23].

Для забезпечення партизанських дій створювали розгалужену мережу тайників з матеріальними засобами і фінансами. Для обладнання використовували колишні піонерські табори, бази відпочинку, закинуті будівлі, промислові споруди, різні будівлі і житлові будинки у сільській місцевості. Подібні бази і склади створювали і на рівнинній частині. Для доставки матеріальних засобів і зброї визначали та готували маршрути. Для зменшення уразливості системи управління повстанських формувань розгортали мережу мобільних ретрансляторів на автомобілях.

Тактика повстанців була розроблена за участі радників з Афганістану, Пакистану, Саудівської Аравії та представників від НАТО. Проаналізувавши дії чеченських повстанських загонів у 1994–1996 рр. і 1999–2000 рр. можемо зробити деякі висновки щодо їх тактики, розкрити сильні та слабкі сторони.

Тактика повстанських формувань включає різні форми і способи боротьби з військами, у т. ч. проведення диверсійно-терористичних актів та агітаційно-пропагандистських заходів. В основу їх тактики покладено принципи партизанської боротьби і терору, головними з яких є:

ухилення від прямих зіткнень на відкритій місцевості з переважаючими силами противника;

відмова від позиційних дій і водночас запекле утримання ключових об'єктів (районів), особливо при веденні бою у великих населених пунктах і горах;

напад на найбільш уразливі об'єкти переважаючими силами;

раптовість дій, прагнення утримувати ініціативу у своїх руках.

Характерними рисами тактики чеченських повстанців були:

швидке зосередження сил для вирішення важливих завдань і їх розосередження при загрозі блокування чи розгрому;

завдання ударів в одному або одночасно кількох районах;

широке використання у якості прикриття мирного населення;

захоплення заручників за межами зони збройного конфлікту [8, с.439].

Тактика повстанських формувань не є постійною і системною, а змінюється залежно від конкретних умов обстановки, вирішуваних завдань і можливостей. Широко застосовували нестандартні, спеціальні способи протидії військам, дії характеризувалися прихованістю, раптовістю і широким використовували військової хитрості.

Тактика повстанців базувалася на добре організованій розвідці, маневреності, умілому застосуванні різних засобів боротьби, особливо мін і фугасів, а також мінометів і зенітних засобів, досконалому знанні місцевості, раптовості дій, швидкому зосередженні сил і засобів, своєчасному виході з бою і відведенні своїх загонів у важкодоступні місця, взаємопідтримці та стійкості в бою.

Повстанські формування вели бойові дії здійснюючи обстріли (вогневі нальоти); обмежений наступ; організацію засідок; здійснювали диверсійні та терористичні акти; вели оборону; захоплювали важливі об'єкти і заручників. При цьому широко застосовували мінно-вибухові загородження; проводячи снайперські дії й активну агітаційно-пропагандистську роботу.

Отже, доцільно виокремити такі *характерні способи дій чеченських повстанців*: переслідування підрозділів противника; ізоляція району бойових дій шляхом блокування, виставлення заслонів на маршрутах; проведення вогневих нальотів; оточення підрозділів: проведення пошуку різноманітними способами (одностороннього, зустрічного, за окремими напрямками, по ділянках) [4, с.63-67].

Великі формування проводили операції по захопленню й утриманню важливих населених пунктів, державних, промислових і військових об'єктів.

Характерною рисою повстанських формувань був широкий спектр їх дій: від окремих терористичних акцій до широкомасштабних наступальних і оборонних дій по захопленню й утриманню стратегічно важливих об'єктів, ставка на раптовість і короткочасність нальотів, на проведення систематичних турбуючих і виснажуючих дій [11, с.82].

До сильних сторін повстанських формувань доцільно віднести:

добре організовану розвідку (у 1996–1998 рр. на території Чечні було розгорнуто п'ять центрів радіорозвідки), персонал цих центрів складали американці й англійці;

використання місцевого населення (жінок і дітей) для вирішення розвідувальних завдань;

маневреність;

вміле застосування зброї, особливо мінометів, зенітних засобів і мін, снайперського вогню;

взаємну підтримку та стійкість у бою;

досконалне знання місцевості давало заколотникам змогу раптово нападати, швидко зосереджувати сили в потрібному місці, своєчасно виходити з бою, переховуватися у важкодоступних місцях;

високі мобілізаційні можливості НЗФ;

чітку систему управління, яка здійснювалася централізовано, з використанням сучасних засобів зв'язку;

сувору дисципліну, яка спиралася на релігійні та тейпові принципи, національно-релігійний фанатизм і готовність до самопожертви (система "смертників", камікадзе);

наявність у загонах добре навчених, досвідчених найманців та інструкторів, які пройшли всебічну підготовку в спеціальних таборах у країнах Близького Сходу та Середньої Азії;

загальну підготовку населених пунктів і місцевості до довготривалої оборони;

створення запасів озброєння, боєприпасів і матеріальних засобів;

широке використання автомобільного та гужового транспорту;

оснащення сучасним озброєнням і спорядженням;

чітка організація ротації (замін) повстанців у зоні бойових дій [11, с.81-82].

Слабкими сторонами чеченських повстанців були:

а) нестача особового складу та ресурсів. Найбільш уразливим для дій повстанських формувань є знищення їх баз постачання, блокування маршрутів постачання підкріплень, зброї та продовольства;

б) уразливою стороною повстанських формувань є їх залежність від підтримки місцевого населення. Зниження або повна її відсутність значно впливає на ефективність їх дій, а у підсумку, відмова місцевого населення від підтримки призводить до затухання партизанської війни;

в) наявні у повстанському середовищі, у т. ч. і серед польових командирів, політичні, релігійні та етнічні розбіжності.

Цікавою, на нашу думку, є тактика **партизанських дій в Афганістані (2001–2011 рр.)**. Виведення радянських військ з Афганістану не принесло в країну миру. Після виведення радянських військ, відомі польові командири, зокрема Захір Шах, Ахмад Шах Масуд, Гульбеддін Хекматіяр та інші продовжили боротьбу з прокомуністичним урядом, який очолював президент Наджибулла, Комуністичним режимом в Афганістані був повалений у 1992 р. Проте між польовими командирами дуже швидко почалася міжусобиця, однією з причин якої була конкуренція навколо розподілу коштів і зброї, що надходили з Пакистану, а також прибутків від наркоторгівлі [3, с.227; 5, с.744].

У 1992–1996 рр. в Афганістані тривала громадянська війна між лідерами ісламських угруповань, допоки до влади не прийшли **таліби***. Жорсткий радикалізм і явна агресивність відштовхнули від уряду Талібану більшість країн. Їх визнали лише Пакистан, Саудівська Аравія й Об'єднані Арабські Емірати. Уряд талібів викорінював у країні все "неісламське", зокрема відомий руйнуванням культурних пам'яток. У 2001 р., не дивлячись на протести й обурення світової спільноти, уряд Талібану здійснив акт вандалізму, знищивши пам'ятку доісламської культури Афганістану – 55-метрової статуї Будди у долині Баміан, зараховані ЮНЕСКО до культурної спадщини людства [3, с.229; 5, с.746]. У світі у цей час зросли акції міжнародного тероризму, який із суспільно-політичного та військово-політичного явища перетворився на одну з головних загроз безпечному існуванню людства. З лютого 1993 р. до вересня 2001 р. у світі відбулося понад 10 резонансних диверсій, в яких загинули та були поранені як військовослужбовці (США, Індії, Саудівської Аравії, Афганістану, Кенії, Танзанії та ін.), так і понад 1500 осіб серед мирного населення країн, в яких ці теракти були здійснені [3, с.229; 5, с.745-747].

Поступово Афганістан став притулком міжнародних терористичних організацій, включаючи "Аль-Каїду". У липні 1999 р. президент США Б. Клінтон наклав на уряд Талібану суворі економічні санкції за сприяння і переховування Усами бен Ладена, "терориста № 1" у світі. Існують докази тогочасних контрактів бен Ладена з представниками ЦРУ, проте ситуація 11 вересня 2001 р. кардинально змінилася. У США було здійснено теракти небачених до цього

* **Талібáн** (*араб.* طالبان – "шукаючі знання", "студенти") – радикальний ісламістський рух, що виник серед пуштунів Афганістану в 1994 р. під проводом Мухамеда Омара (Мулли Омара). Рух заснувався на суворій формі сунітського ісламу і прийшов до влади в країні у вересні 1996 р., а потім знову у серпні 2021 р. після виведення з Афганістану американських військ. Рух відомий своїми жорсткими правилами, що запровадили суворі закони, які обмежують права жінок, включаючи заборону на освіту, роботу, телебачення, музику та Інтернет, подорожі, обов'язкове носіння хіджабу, зобов'язав чоловіків відрощувати бороди, а також запровадив жорсткі покарання за крадіжки та інші злочини відповідно до норм шаріату (*прим. – авт.*).

масштабів. Одночасно було викрадено чотири пасажирські літака, два з них з інтервалом 18 хв. врізалися у Всесвітній торговельний центр у Нью-Йорку (загинуло майже 3000 осіб). Ще один літак упав на Пентагон, а четвертий – упав на землю неподалік від Пітсбурга. Загалом у цих авіакатастрофах загинуло 233 пасажира та 33 члени екіпажів [3, с.230; 5, с.747; 13, с.385-386].

17 вересня 2001 р. президент США Дж. Буш оголосив про початок Америкою "хрестового походу проти зла нового типу, яким є тероризм". Попри непевні докази причетності бен Ладена до терактів у Нью-Йорку, саме його оголосили їх організатором, а головним об'єктом помсти – Афганістан, який надав йому притулок. У промові в Конгресі США президент ультимативно зажадав від талібів видачі бен Ладена. Проте Мулла Омар відхилив їх вимоги і потребував переконливих доказів його вини. Тоді ж Дж. Буш почав формувати анти-терористичну коаліцію та операцію "Безмежна свобода" проти режиму талібів в Афганістані та бойовиків ісламської терористичної організації "Аль-Каїда". Операція передбачала: змінити військово-політичну ситуацію на Середньому Сході, забезпечити неможливість використання території Афганістану міжнародними терористичними угрупованнями, відплатити за загибель громадян США 11 вересня 2001 р., запровадити довготривалу військову присутність в Афганістані й державах Середньої Азії. Коаліцію підтримали Узбекистан, Киргизстан, Таджикистан, Туркменістан і Грузія надавши свої аеродроми, а Росія відкрила для них свій повітряний простір. В коаліцію увійшли й арабські країни. Пакистан відкликав з Афганістану своїх послів і надав свої військові бази США. 25 вересня Об'єднані Арабські Емірати, Бахрейн, Оман і Катар розірвали з урядом Талібану дипломатичні відносини, що призвело до їх міжнародної ізоляції. На початок операції "Безмежна свобода" 7 жовтня 2001 р. Талібан контролював, за різними оцінками, 85–95% території Афганістану. Цього ж дня США спільно з Північним і Південним альянсом розпочали проти ісламського руху Афганістану воєнні дії. 7 грудня сили Південного альянсу, якими командував Хамід Карзай зайняли місто і гірську базу бен Ладена Тора-Бора. Мулла Омар втік, бен Ладена – не знайшли, але режим Талібану пав [3, с.229-230; 5, с.747-748]. У країні знову відновилась світська влада та порядок.

Розглянемо тактику талібів проти коаліційних сил. Доречно зазначити, що військове командування Талібану розуміло необхідність утримувати головні міста країни та особливо важливі об'єкти у містах. Не дивлячись на значну перевагу у силах і засобах коаліції таліби чинили активний опір, що призводило до значних втрат серед коаліційних сил.

Специфічні природно-географічні умови країни та вміння талібів пристосувати до них партизанську тактику багато в чому компенсували вирішальну військово-технічну перевагу елітних частин американської армії. Шеф їх центрального командування генерал Т. Френкс змушений був визнати: "Наші високотехнологічні системи не завжди переважають відсталі методи і засоби" [22, с.17].

Бойова активність талібів пожвавилася з весни-літа 2005 р. Чисельність їхніх бійців становила 2–3 тис., проте вони спиралися на підтримку населення низки провінцій, а на не контрольованих урядом територіях Пакистану вперше з 2001 р. відновили навчальні центри. Там убили кількох лідерів племен, які виступали проти Талібану та "Аль-Каїди". У південних і східних районах Афганістану (провінції Хост, Пактія, Пактіка, Забуль), населених переважно пуштунськими племенами, відбувалося перегрупування талібських загонів. Зріс бойовий потенціал загонів відомого лідера моджахедів боротьби з радянськими військами Г. Хекматіяра, який відкидав примирення з урядом Х. Карзая [18, с.7].

Ареною основних бойових дій стали гірсько-пустельні райони країни, переважно прикордоння з Пакистаном. Ісламісти, дотримуючись тактики відпрацьованої ще у війні 1979–1989 рр., не залишали спроб завдавати *ударів і по силах противника у містах, тероризувати верхівку легітимної влади, влаштовувати диверсії*. Так, наприклад, 10 листопада 2002 р. у Кабулі був убитий начальник управління Головного штабу прикордонних військ Раджі. Співробітники "Дельти" запобігли замаху на Х. Карзая. Про початок *терористичної кампанії* у містах із залякування населення та попередження його співробітництва з проамериканським режимом засвідчив вибух у червні 2005 р. в одній з мечетей Кандагара (загинуло понад 40 осіб) [21, с.2].

Противники прозахідного режиму пішли шляхом іракських федаїнів і зробили ставку на *підпільну боротьбу*. Із 181 вояків американської армії, які загинули від початку операції 2001 р., понад 100 – вбиті під час нападів збройного підпілля. За два місяці до парламентських виборів 18 вересня 2005 р. ісламісти вбили 5 кандидатів, здійснили замахи на трьох жінок-кандидатів, загинуло 40 солдатів і 50 поліцейських, 6 лояльних до влади мулл. Загалом у день виборів по країні загинуло 14 осіб [3, с.239].

Не менш цікавим, на нашу думку, є досвід **партизанських дій в Іраку (2003–2011 рр.)**[*]. Майже одразу після завершення операції "Свобода Іраку" (20.03.–01.05.2003, тобто формального завершення бойових дій) у країні розгорнулася партизанська війна. Уже в квітні 2003 р. командування Коаліційних сил розпочало створення перших поліцейських підрозділів, зокрема 12 квітня 2003 р. командування коаліції звернулося до співробітників іракської поліції із закликом "брати участь у відновленні порядку в

[*] **Війна в Іраку (2003–2011)** – затяжний воєнний конфлікт, що розпочався 20 березня 2003 р. вторгненням Коаліційних військ на чолі з США та Великою Британією (операція "Свобода Іраку") без мандата ООН. Головна мета – повалення режиму Саддама Хусейна та знищення нібито наявної зброї масового ураження. Активні бойові дії завершилися 1 травня 2003 р. взяттям Багдада, що у підсумку призвело до тривалої окупації та партизансько-повстанського руху. Американські війська офіційно були виведені з Іраку 15 грудня 2011 р. Однак з початком громадянської війни в Сирії та територіальної експансії Ісламської держави Іраку та Леванту (ІДІЛ) адміністрація президента США Б. Обами ухвалила рішення про повернення своїх військ в Ірак у 2014 р. (*прим. – авт.*).

Багдаді", а 14 квітня 2003 р. у Багдаді з'явилися перші спільні патрулі іракських поліцейських і солдатів США, водночас британські війська розпочали роботу по створенню поліції у Басрі.

15 квітня 2003 р. представник Комітету начальників штабів ЗС США генерал С. Мак-Кристал заявив про завершення широкомасштабної військової операції. Проте зазначалося, що триває опір "озброєних ополченців, бійців республіканської гвардії і терористів" [20, с.529]. Одночасно мали місце випадки нападів партизанів на коаліційні сили: зокрема, 28 квітня 2003 р. (у день народження С. Хусейна) у місті Мосул по американських військах відкрили кулеметний вогонь, бій тривав протягом 45 хв. і став найбільшим інцидентом з моменту встановлення контролю сил коаліції над містом. 1 травня 2003 р. президент США Дж. Буш виголосив промову відому як "Місія виконана", якою фактично оголосив про військову перемогу США у війні в Іраку.

Ірак було поділено на кілька окупаційних зон. Багдад, "сунітський трикутник", північні райони Іраку і західну провінцію Аль-Анбар контролювали американські війська. Населені шиїтами райони на південь від Багдада були зонами відповідальності Багатонаціональної дивізії, до складу якої увійшли підрозділи з Польщі, Іспанії, Італії, України та кількох країн Центральної Америки. На крайньому півдні Іраку у Басрі дислокувався британський контингент. Для управління окупованою країною наприкінці квітня 2003 р. було створено Тимчасову коаліційну адміністрацію, завдання якої полягало у створенні сприятливих умов передачі влади новому іракському уряду [2].

Непродумані військово-політичні кроки США стали передумовою утворення потужної соціальної бази іракського руху опору. Одним із перших кроків Тимчасової адміністрації, на нашу думку, став розпуск іракської армії та поліції, який спричинив одномоментно 400-тисячну масу безробітних й озлоблених чоловіків. Відмова від влаштування на цивільну службу членів Партії арабського соціалістичного відродження (БААС) загнала частину її членів у підпілля, серед населення недостатньо активно проводили роз'яснювальну роботу. "До кінця серпня вияснилося, що американська місія висить на волосинці... До того часу окупація вже зазнала поразки в очах іракських мешканців, не виправдавши їхніх сподівань на відновлення стабільності й мінімальних економічних стандартів... "Аль-Каїда" та інші ісламські бойовики проникали до країни" [9, с.206].

Початок *активної фази іракської партизанської війни* припав приблизно на травень–червень 2003 р., яка розвивалася на фоні зростаючого невдоволення місцевого населення присутністю й політикою окупаційної адміністрації. На той час уже 73% мешканців Багдада вважали, що Коаліційні (Багатонаціональні) сили (БНС) незадовільно вирішують проблеми забезпечення їх безпеки. У червні відбулися великі маніфестації в столиці, Басрі та інших містах. Американська розвідка спочатку оцінювала вилазки бойовиків як окремі інциденти, продиктовані відчаєм просаддамівських сил. Проте вже 18 червня 2003 р. заступник міністра оборони США П. Вулфовиць виступив із зізнанням, що в Іраку йде партизанська війна, напади на вояків Багатонаціональні сили здійснюються щоденно [3, с.219].

У червні 2003 р. Багатонаціональні сили очолювані США провели першу значну операцію "Удар по півострову" (9–13.06.2003 р., затримано 397 повстанців [2]) після повалення режиму С. Хусейна, спрямовану проти партизанського руху, який набирав силу. Партизани захопили велику кількість зброї та боєприпасів на складах колишньої іракської армії під час безвладдя, що панувало у перші тижні після повалення саддамівського режиму.

Літо 2003 р. започаткувало зародження іракського партизанського руху. Його особливістю стало те, що він увібрав у себе угруповання різної, а часом і протилежної політичної, ідеологічної та релігійної спрямованості, по суті, вчорашніх запеклих противників. Формування цього періоду представлені багатонаціональним складом, зокрема бааситського, сунітського, шиїтського спрямування й "Аль-Каїди", які залучалися у конфлікті з ідеологічних і фінансових причин, у т. ч. через суттєвий пропагандистський вплив. Серед основних можемо виокремити такі:

формування з колишніх співробітників силових структур режиму С. Хусейна: Загальне збройне угруповання збройних сил Іраку (колишні армійці); Рух з визволення Іраку (вояки Республіканської гвардії); Опір за визволення Іраку (вояки Республіканської гвардії особливого призначення); Народний рух опору за визволення Іраку (співробітники органів держбезпеки);

формування з колишніх функціонерів партії БААС: "Повернення", яке активно діяло у столиці та великих містах країни; "Голова змії";

загони ісламістів і сепаратистів: "Революція Іраку – збройні бригади аль-Анбара"; "Прихильники ісламу" – ісламські радикали, причетні до нападів на приміщення місії ООН та Міжнародного комітету Червоного Хреста у Багдаді;

угруповання сунітів: "Бригади аль-Фарух"; організація "Чорний прапор", які спеціалізуються на диверсіях у нафтовій промисловості;

формування ісламських бойовиків, які прибули з-за кордону, зокрема "Бойовики переможної секти" та її збройне крило "Бригада мучеників аль-Хаттабі"; пов'язані з "Аль-Каїдою" "Салафісти Іраку", які завдають ударів тим іракцям, що співпрацюють з окупаційною владою [3, с.219-220; 15, с.212-213].

22 червня заявили про своє існування ще два військово-політичні угруповання, які відкидали зв'язок з прихильниками С. Хусейна, проте наголошували на прагненні непримиренно боротися з американцями аж до повного їх виходу з країни [3, с.219].

Військова операція в Іраку загострила ситуацію в країні, сприяла ескалації терористичної діяльності за участю представників інших ісламських держав. Серед учасників опору, які виступали проти міжнародних Коаліційних сил та створених за підтримки США органів цивільної адміністрації та уряду країни, були вихідці з Йорданії, Сирії, Ірану, Лівану, Ємену, Палестини, Чечні, Марокко, Саудівської Аравії, Єгипту, Алжиру і Сомалі. До початку 2004 р.

в Іраку, за американськими даними, діяло 1–3 тис. іноземних бойовиків, з яких 300 потрапило в полон. Серед моджахедів були представники всіх ісламських конфесій, а також християни. Частина формувань підпілля змішана за складом, частина – складалася виключно з іракців, включаючи й смертників [1, с.212-214; 19, с.18-22].

Осередком партизанського опору на той час був "сунітський трикутник", особливо провінція Аль-Анбар, де центром спротиву стало місто Ель-Фалуджа. Під час двох битв за місто навесні та восени 2004 р. повстанці успішно дали відсіч американсько-британським військам та їх союзникам, відстоявши його. Цим осередком керував один з ватажків відомої екстремістської організації "Таухід валь-джихад" Абу Рашид. Очолювана ним рада моджахедів (13–15 командирів) розподілила обов'язки так, що частина груп вела *спостереження і розвідку*, інша частина займалася *тиловим забезпеченням*, окремі групи – *обстрілом колон і виведенням з ладу ліній зв'язку, викраденням людей*. Аби підтримувати авторитет серед населення, угруповання дбало про знищення лжебойовиків, які грабували мешканців міста [1, с.214].

Вважається, що сили опору фінансувалися сунітськими колами як основною опорою колишнього диктатора. Навчання партизанів, за іншими даними, проходило у тренувальних таборах на території Сирії та Ірану, які також фінансували та постачали бойовиків. Повстанці вчиняли різні терористичні акції проти уряду Іраку, окупаційних сил і прихильників нового режиму [2].

Тактика повстанців. Основними способами ведення партизанських дій в Іраку були: *терористичні акти*; *точкові збройні напади* (атаки маневрених бойових груп) *на бази, військову в'язницю*; *обстріли противника* (мінометні, снайперські, гранатометні та переносні установки з некерованими реактивними снарядами (НКРС, *рос*. – НУРС); *засідки на конвой*; *дії снайперів-одинаків*; *атаки смертників* (на замінованих автомобілях або поясами з вибухівкою); *диверсії*; *напади на населені пункти*; *застосування саморобних вибухових пристроїв* (СВП); *використання імітації відступу*.

На *терористичні акти і диверсії* припадає левова частка збройних акцій руху опору коаліційним силам в Іраку. Об'єктами нападів були адмінбудівлі і представництва іноземних держав, поліцейські дільниці і навчальні заклади, казарми підрозділів БНС і новоствореної армії Іраку, інфраструктура, патрулі, автомобілі й бронетанкові колони, часто – звичайні місця скупчення людей, насамперед відомі східні базари. Крім Багдада, часті *теракти* і *засідки* влаштовували в таких містах, як Басра, Тікрит (батьківщина Саддама), Ель-Фалуджа. У 2004 р. у середньому відбувалося 25 нападів на вояків коаліції на день. Зазвичай, завдавали миттєвих "ударів–відходів" із застосуванням мінометів, гранатометів, реактивних установок, стрілецької зброї, і моджахеди ретирувалися не вступаючи у бої з силами коаліції [3, с.222].

На початку конфлікту повстанці здійснювали поодинокі *рейди* на невеликі об'єкти, але вже у 2004 р. перейшли до нападів на добре *захищені бази* та *колони*. Найпоширенішими ударами по БНС були *підриви замінованих машин або скеровування їх смертниками на об'єкти та живу силу противника і скупчення населення, влаштування засідок, швидкі обстріли з мінометів, реактивних установок і РПГ*. При цьому, якщо раніше, після підриву міни під вантажівкою, повстанці намагалися якнайшвидше розбігтися, то згодом після вибуху міни вони зосереджували вогонь із гранатометів та автоматичної зброї по солдатах, які охороняли колону, а потім переносили його на інші машини. Для нападу застосовували системи зброї, здатні вести вогонь із закритих позицій: мінометні установки, як правило, у вантажівках або пасажирських автомобілях, переносні установки з НКРСами. Для гранатометників влаштовували прихисток типу "лисячих нір" [2].

Найбільших втрат силам коаліції завдавали СВП, які розміщували на узбіччі дороги та приводили в дію (часто – дистанційно) під час проходження конвою або патруля міжнародної коаліції. Так, у вересні 2005 р. загинуло 49 (7 осіб – не бойові втрати) американських і 3 британських вояки. З них 37 американців – від СВП, включаючи керовані смертниками автомобілі, а решта – жертви мін на дорогах [17, с.73]. Найсмертоносніша конструкція СВП включала кумулятивний заряд спрямованої дії, інфрачервоний лазер і датчик, який спрацьовував після перетину лазерного променя. Таку конструкцію встановлювали на дорозі в неактивному стані й активізували дистанційно безпосередньо перед проходженням військової колони.

Нападаючи на бази, моджахеди потай мінували місцевість у районі її розташування, після чого обстрілювали табір з мінометів і гранатометів. Військовослужбовці, які вибігали для того, щоб зайняти оборонні позиції, потрапляли на мінне поле. Втрати під час таких рейдів з боку оборонців були досить відчутними.

Повстанці активно залучали *снайперів-одинаків*. У деяких випадках створювали групу прикриття у складі 1–2 помічників і спостерігача на рухомому засобі (мопед, велосипед). Як мобільне укриття використовували автотранспорт. До снайперів висували такі вимоги: уразити ціль на відстані 600 м з першого пострілу та вести прицільний вогонь на відстані 600–1000 м. Але з початком війни тактичні прийоми снайперів змінилися. Передусім це стосувалося місця перебування об'єкту ураження, максимальна відстань до цілі повинна бути не більше, ніж 350–400 м. При проведенні деяких операцій для страховки, на дахах будинків розташовували снайперів-спостерігачів. Об'єктами ураження були офіцери, зв'язківці, снайпери, обслуги вогневих засобів, водії транспортних засобів, перекладачі, медичний персонал. Короткий вогневий контакт і швидкий відхід – саме ця тактика доводила противника до паніки та стану надзвичайної нервозності, війська переходили до оборони, після чого на територіях, підконтрольних Коаліційним військам, зосереджувалися великі партизансько-терористичні формування зі 100 і більше бойовиків [2].

У результаті активної фази партизансько-підпільної війни втрати коаліційних військ набагато перевищили військову кампанію "Свобода Іраку" 2003 р. (211 убитих) [12, с.2]. За даними, лише з травня 2003 р. до травня 2004 р. в Іраку було зафіксовано 15 тис. випадків підривів СВП, у т. ч. з людськими жертвами [2]. За іншими даними, з березня 2003 р. до березня 2005 р. загинуло 1462, отримали поранення 10 тис. американських вояків, загинуло 86 англійських, 20 італійських, 18 українських і 50 військовослужбовців інших держав – учасниць коаліції, до липня 2005 р. безповоротні втрати американців досягли – 1700 осіб, а до грудня вже перевищили 2000 осіб). Лише за червень 2005 р. загинули 296 іракських поліцейських і військовослужбовців, 477 цивільних громадян [3, с.223-224; 14, с.7].

Іншою формою боротьби стала організація *терактів*. Зокрема були підриви замінованих автомобілів, атаки на мечеті, захоплення заручників із жорсткими вимогами або заради звільнення з полону своїх спільників. Першим з терористичних актів став підрив посольства Йорданії у серпні 2003 р. Наступною ціллю терористів стала штаб-квартира ООН у Багдаді, причому серед загиблих 19 серпня 2003 р. виявився голова іракської місії – Спеціальний представник Генсека ООН в Іраку, бразильський дипломат і авторитетний миротворець Сержіу Вієйра ді Меллу.

Найбільшою й успішною терористичною атакою на представників Коаліційних сил став підрив казарм італійського контингенту в Насирії у листопаді 2003 р. Крім того, повстанці інколи здійснювали *напади* на цілі міста та населені пункти для встановлення контролю над ними та утворення так званих партизанських зон – територій, контрольованих повстанцями. Найбільшою їх зоною стала провінція Аль-Анбар на заході країни, яка на початок осені 2006 р. практично не була контрольована ані Коаліційними військами, ані новим іракським урядом. При протистоянні БНС повстанці активно використовували релігійно-культові споруди [2].

За підсумками міжнародних експертів, з 20 лютого 2003 р. до 2005 р. в Іраку загинуло 28 865 цивільних громадян. При цьому 37% з них стали жертвами дій військ Коаліційних військ, 45% – терору антиамериканського підпілля; у 2004 р. загинуло удвічі більше людей, ніж у попередньому, половина з них – у Багдаді, 20% жертв становили жінки і діти [3, с.223-224, 227; 6, с.7].

Ситуацію, в якій опинилися БНС, неможливо уявити без урахування реального ставлення до них місцевого населення. Соціологічні дослідження свідчать, що проти присутності американців налаштовано 98,8% мусульман-шиїтів (58% населення Іраку), 98,2% сунітів (30%), 23% курдів, у останніх були всі підстави ненавидіти режим С. Хусейна [7, с.2].

Отже, в цілому повстанці проти Коаліційних військ вели "асиметричну війну", сутність якої полягала в партизанській тактиці з використанням СВП в організації та проведенні засідок, рейдів та інших тактичних дій партизанської війни при ретельному маскуванні маневрів, розсипних ударів після вчинення атак. Повстанці, для досягнення свої цілей, не дотримувалися вимог Женевської конвенції, а застосовували такий тактичний прийом як "живий щит" з цивільного населення. Крім того, партизани активно використовували прийоми інформаційної війни, а характерною особливістю їх дій було уникнення бойових зіткнень із регулярними військами.

Підсумовуючи вищевикладене, можемо зробити такі висновки:

історичний досвід засвідчив, що способи партизанських (повстанських) дій мають свої особливості, які залежать від фізико-географічних умов району дій (операції) та оперативної обстановки, змісту завдань, які отримані партизанськими (повстанськими) формуваннями, наявних сил і засобів, рівня забезпечення їх дій, бойового досвіду особового складу і командних кадрів, а також протидиверсійних заходів регулярних військ з пошуку та знищення партизанів (повстанців) в районах їх дій та інших чинників;

до бойових дій партизанських (повстанських) формувань можемо віднести такі способи: наступальні й оборонні дії по захопленню й утриманню важливих населених пунктів, промислових об'єктів й інфраструктури; обмежений наступ на міста (населені пункти); блокади опорних пунктів і гарнізонів; оборона гірських долин і кишлаків та ін. При цьому широко застосовували мінно-вибухові загородження, снайперські дії й активно велася агітаційно-пропагандистська робота;

під час ведення спеціальних дій використовували такі способи виконання завдань: раптові напади (нальоти, штурми), обстріли (вогневі нальоти) з використанням мінометів, снайперських груп, гранатометів і некерованих ракетних снарядів; вибіркові збройні напади (атаки маневрених бойових груп) на військові бази; дії снайперів-одинаків; засідки проти колон забезпечення, конвоїв і патрулів;

диверсійні та терористичні акти; саботаж; руйнування військових і цивільних об'єктів і комунікацій, створення паніки у ворожому тилу. В деяких випадках застосовували атаки смертників (на замінованих автомобілях або з поясами начинених вибухівкою), застосування саморобних вибухових пристроїв.

Під час організації партизанської (повстанської) боротьби на тимчасово окупованій території, основну увагу приділяли підготовці фахівців саме з цієї діяльності.

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MEDICAL SCIENCES

PROGRESS IN MANAGEMENT OF LOCALLY ADVANCED RECTAL CANCER

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Abstract

The incidence of rectal cancer, particularly among younger adults, has risen substantially over recent decades [1], prompting renewed focus on optimizing diagnostic and therapeutic strategies. Management has evolved from surgery alone to a multimodal approach integrating chemoradiation, total mesorectal excision (TME), and systemic chemotherapy. Landmark clinical trials have shaped current standards, demonstrating improvements in local control and disease-free survival. More recently, total neoadjuvant therapy (TNT) has redefined treatment sequencing by delivering all systemic therapy before surgery, enhancing tumor response and reducing distant metastases [8,9]. Additionally, organ-preserving approaches, including non-operative management for patients achieving a complete clinical response, are increasingly being explored [14,15]. This review summarizes the historical development of rectal cancer management, highlights pivotal clinical trials, and discusses emerging strategies that may further individualize therapy.

Keywords: rectal cancer, therapeutic management.

Introduction

Rectal cancer represents a significant and growing global health concern, with projections indicating a marked increase in incidence among young adults [1]. Historically, surgery was the primary treatment modality; however, high rates of local recurrence limited long-term outcomes. Over the past four decades, treatment has transitioned toward a multimodal framework integrating surgery, radiation therapy, and chemotherapy. These advances have substantially reduced locoregional recurrence and improved disease-free survival (DFS).

Surgical Innovation: The Role of Total Mesorectal Excision

The introduction of total mesorectal excision (TME) in the 1980s represented a turning point in rectal cancer surgery [2]. By removing the rectum together with the entire mesorectal envelope containing regional lymphatics, TME significantly reduced local recurrence rates. Achieving clear circumferential resection margins became recognized as the most critical predictor of local control.

While TME remains the gold standard for resectable rectal cancer, it is associated with potential long-term morbidity. Consequently, organ-preserving approaches have been explored in selected early-stage tumors. The TREC trial demonstrated that short-course radiotherapy followed by local excision may achieve favorable oncologic outcomes while preserving quality of life in selected patients [4].

Development of Trimodal Therapy

Early Adjuvant Approaches

Initial efforts to improve outcomes beyond surgery alone focused on postoperative radiation and chemotherapy. Early randomized studies demonstrated that combining radiation with fluoropyrimidine-based chemotherapy reduced local recurrence and improved DFS compared with surgery alone [11].

Radiobiological principles suggested that preoperative radiation might be more effective than postoperative treatment due to improved tumor oxygenation and lower required radiation doses.

Preoperative Radiation Trials

The Swedish Rectal Cancer Trial demonstrated that short-course preoperative radiation significantly reduced local recurrence and improved overall survival compared with surgery alone [3]. Subsequently, the Dutch TME trial confirmed that combining preoperative radiation with standardized TME further enhanced local control [5,6].

The addition of concurrent chemotherapy to preoperative radiation further improved local tumor control and pathologic response rates [11].

Preoperative Versus Postoperative Chemoradiation

The German Rectal Cancer Study Group conducted a landmark trial comparing preoperative and postoperative chemoradiation [10]. Preoperative therapy resulted in lower local recurrence, reduced toxicity, improved compliance, and higher rates of sphincter preservation. Although overall survival did not significantly differ, these findings established preoperative chemoradiation as the standard of care.

The role of adjuvant chemotherapy after chemoradiation and surgery remained controversial. The EORTC 22921 trial failed to demonstrate a significant survival advantage with postoperative chemotherapy [11], and similar findings were observed in subsequent analyses [12]. Poor compliance with postoperative chemotherapy regimens was considered a contributing factor.

Short-Course Versus Long-Course Radiation

Two primary neoadjuvant radiation strategies emerged: long-course chemoradiation and short-course radiotherapy. The Stockholm III trial demonstrated comparable oncologic outcomes between short- and long-course regimens, with fewer postoperative complications when surgery was delayed [7]. These findings supported flexibility in radiation scheduling and facilitated integration of systemic chemotherapy prior to surgery.

Addressing Distant Metastases: Emergence of Total Neoadjuvant Therapy

Despite improvements in local control, distant metastases remained a major cause of mortality. Total neoadjuvant therapy (TNT) was developed to address this limitation by administering all systemic therapy before surgery.

RAPIDO and PRODIGE 23 Trials

The RAPIDO trial demonstrated reduced disease-related treatment failure and fewer distant metastases with short-course radiation followed by chemotherapy prior to surgery [8]. Similarly, the PRODIGE 23 trial showed improved metastasis-free survival and higher pathologic complete response (pCR) rates with induction FOLFIRINOX before chemoradiation and surgery [9]. Although overall survival differences were modest, both trials significantly improved systemic disease control and tumor response rates.

Optimization of TNT Sequencing

The CAO/ARO/AIO-12 trial compared induction chemotherapy (before chemoradiation) with consolidation chemotherapy (after chemoradiation) [13]. Consolidation therapy produced higher pCR rates and better treatment compliance, suggesting that sequencing may influence response and organ preservation potential.

Organ Preservation and the "Watch-and-Wait" Strategy

Higher complete response rates following TNT prompted investigation into non-operative management strategies. Early work by Habr-Gama and colleagues demonstrated the feasibility of non-operative management in patients achieving complete clinical response (cCR) [15].

The OPRA trial further evaluated this approach, demonstrating that patients achieving cCR after TNT could safely undergo watch-and-wait management without compromising disease-free survival [14]. Consolidation-based TNT was associated with higher rates of organ preservation.

Strict surveillance protocols, including endoscopy, digital rectal examination, and MRI, are essential for safe implementation of this strategy.

Balancing Efficacy and Overtreatment

Although aggressive multimodal therapy improves oncologic outcomes, it carries risks of functional impairment and diminished quality of life. Decisions regarding treatment intensity must balance oncologic benefit with patient-centered outcomes. Current clinical guidelines emphasize individualized treatment planning [17].

Current Standard and Future Directions

Modern management of locally advanced rectal cancer increasingly favors total neoadjuvant therapy followed by TME, with selective non-operative management for complete responders [8,9,14]. These approaches improve systemic disease control, enhance tumor response, and expand opportunities for organ preservation.

Future research is focused on identifying predictive biomarkers, refining imaging-based response assessment, and optimizing patient selection for treatment de-escalation.

Conclusion

Over the past four decades, rectal cancer management has evolved dramatically. The integration of TME [2], preoperative chemoradiation [10], and total neoadjuvant therapy [8,9] has improved local control and reduced distant metastases. The emergence of organ-preserving strategies such as watch-and-wait represents a paradigm shift toward personalized treatment. Continued refinement of multimodal therapy aims to maximize survival while minimizing treatment-related morbidity.

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POLITICAL SCIENCES

STATE STRATEGY FOR THE FORMATION OF CIVIC IDENTITY IN THE KYRGYZ REPUBLIC: MECHANISMS AND CHALLENGES

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Abstract

This article provides a comprehensive analysis of the influence of state institutions on the evolution of identity in contemporary Kyrgyzstan. The main focus is on studying the process of changing development vectors: from an emphasis on ethnic identity to civic unity, as enshrined in the national doctrine of "Kyrgyz Zharany." The formation of civic identity is a key aspect in the development of any multinational society, especially in the context of globalization and constant political and social change. In Kyrgyzstan, this process is particularly relevant given the diversity of the ethnic and cultural composition of the population. Civic identity serves not only as the basis for the formation of national unity, but also as an important factor in ensuring political stability, economic development, and social cohesion. State policy plays a decisive role in the formation of civic identity, influencing citizens' perception of their belonging to the nation.

Keywords: Kyrgyz Republic, public administration, civic unity, "Kyrgyz Zharany," nation building, social integration, political stability, sovereignty.

Introduction. In Kyrgyzstan, over the past decades, there have been active attempts by the state to create conditions for the formation of a national identity through various political and social mechanisms, such as reforms in education, cultural policy, information strategy, and legislative changes. However, despite these efforts, the process of forming civic identity faces a number of challenges, including problems of ethnic integration, political instability, and the absence of a unified state ideology. Civic identity is an important component of social unity and sustainable development in a multinational society. In Kyrgyzstan, state policy plays a key role in the formation of civic identity, especially in the context of post-Soviet transformations (Smith, 2019). The aim of this study is to analyze the impact of state policy on the processes of civic identity formation in Kyrgyzstan. The purpose of this article is to examine the influence of state policy on the processes of civic identity formation in Kyrgyzstan, identify key directions and strategies, and assess their effectiveness. The analysis will be based on a study of historical and contemporary trends in state policy, as well as an assessment of their impact on public consciousness and civic self-awareness among the country's population. The formation of civic identity in Kyrgyzstan takes place in a unique cultural, historical, and social context that combines elements of traditional culture, Soviet heritage, and contemporary global challenges. One of the key objectives of state policy is to foster a sense of belonging to a national identity among citizens, which contributes to strengthening unity and preventing ethnic conflicts. Particular attention is paid to educational policies aimed at fostering patriotism and tolerance, introducing courses on the history and culture of Kyrgyzstan into school curricula, and promoting the Kyrgyz language as a language of interethnic communication. These measures are designed to strengthen the sense of community among young people and encourage awareness of their role in society.

In addition, state institutions actively use the media to promote civic values and unity, presenting successful examples of integration and cooperation between different ethnic groups. The introduction of new holidays and symbols, the holding of mass events and competitions aimed at strengthening national pride—all these are tools with which the state attempts to shape a national identity.

However, the impact of state policy on the formation of civic identity remains ambiguous. In a complex social and economic situation, as well as in conditions of political instability, state policy faces difficulties in implementing its initiatives. Assessing the effectiveness of these measures requires in-depth analysis, including both quantitative and qualitative research methods. Thus, studying the impact of state policy on the processes of forming civic identity in Kyrgyzstan is a relevant and important task that contributes to a better understanding of the mechanisms of integra-

tion and strengthening of national unity in a multinational society. The contemporary challenges facing Kyrgyzstan make the issue of shaping civic identity particularly important. Political crises, social inequality, migration processes, and regional differences in economic development—all these factors have a significant impact on citizens' perception of their role in society and their sense of belonging to a single nation. In this context, public policy acts not only as a mechanism for regulating social relations, but also as a tool capable of steering the processes of identity formation in the right direction. Public policy in the field of civic education plays an important role in consolidating society. The implementation of programs focused on civic education, increasing legal literacy, and fostering a culture of civic participation contributes to the development of an active civil society. Citizen participation in decision-making, including local self-government and public councils, shapes a conscious attitude toward national identity and stimulates a sense of responsibility for the future of the country.

Against the backdrop of growing civic engagement and the increasing influence of social media, the state is also faced with the need to adapt its approaches to shaping civic identity. In the context of digitalization and free access to information, young people are often exposed to alternative ideologies that may contradict official narratives. In response to these challenges, state policy must take into account the characteristics of the modern media environment and develop strategies aimed at promoting national values through digital platforms. The problem of forming civic identity in Kyrgyzstan is also complicated by the diversity of ethnic and religious groups, each of which has its own cultural characteristics and historical roots. In this context, successful state policy should be based on the principles of inclusiveness and respect for cultural diversity, creating space for dialogue and mutual enrichment. Institutions dealing with issues of ethnocultural policy should actively engage with local communities to develop initiatives that contribute to strengthening a sense of national belonging.

The formation of civic identity in Kyrgyzstan is closely linked to historical processes that have influenced the development of the country's political and social structure. The legacy of the Soviet period, with its collectivist ideology and attempts to create a single Soviet people, has left its mark on the perception of civic identity in the post-Soviet era. After gaining independence, Kyrgyzstan faced the need to rethink its national identity and search for new symbols and values that could unite its multi-ethnic society. An important element of state policy in shaping civic identity is the legal regulation of issues of nationality and citizenship. The Constitution of Kyrgyzstan and other legislative acts define the rights and obligations of citizens, forming the legal basis for the development of identity. However, in practice, the implementation of these norms often faces difficulties caused by political instability and administrative barriers. The effective realization of citizens' rights and ensuring the equality of all ethnic groups before the law are key conditions for the successful formation of a common identity.

In the context of government policy to strengthen civic identity, programs aimed at the social integration of vulnerable groups, including migrants, ethnic minorities, and young people, play a special role. Support for such programs at the state level, including language training, vocational training, and social adaptation projects, helps create conditions for the active participation of all citizens in the country's public life. At the same time, it is important that such initiatives are not only offered but also actively promoted and supported at the local level. The state's cultural policy also plays a significant role in shaping civic identity. The promotion of common cultural values, support for national holidays, and the development of cultural institutions and projects aimed at preserving and popularizing cultural heritage contribute to the creation of a common background that helps citizens realize their belonging to a single nation. It is important that such measures combine respect for the traditions of all ethnic groups living in the country and emphasize values and historical events that are common to all citizens.

Thus, state policy has a significant impact on the processes of civil identity formation in Kyrgyzstan. The future of society and its ability to withstand the challenges of globalization and internal instability depend on how effectively the state can integrate ethnic, cultural, and social differences into a single national narrative. Studying these processes is an important step towards developing more effective strategies for strengthening civic unity and social harmony in multi-ethnic Kyrgyzstan. Civic identity is defined as a sense of belonging to a political and social community based on citizenship and shared values (Anderson, 1991). In Kyrgyzstan, the process of forming civic identity is complicated by the multi-ethnic composition of the population and the historical legacy of Soviet ideology (Linz & Stepan, 1996). Government policy in Kyrgyzstan faces challenges related to the diversity of ethnic groups. An important aspect is creating conditions for preserving ethnic diversity while strengthening a common civic identity. Multiculturalism policies and support for cultural projects, such as the celebration of national and ethnic holidays, play an important role in the integration process (Roberts, 2017). Support for such events promotes dialogue between different groups, strengthening unity in society.

Kyrgyzstan's economic policy, aimed at improving living standards and reducing poverty, plays an important role in shaping civic identity. Support for vulnerable groups through social programs and subsidies helps to strengthen trust in the state and increase civic loyalty (Sadykov, 2021). The development of economic initiatives, such as support for small and medium-sized businesses, also stimulates a sense of belonging to society, especially among young people and entrepreneurs. How identity politics contributes to the development of local self-government and local communities. One of the instruments of state policy in Kyrgyzstan is the development of local self-government, which contributes to the strengthening of civic identity at the local level (Baimatov, 2021). Decentralization of power and support for local initiatives allow citizens to participate more actively in public life and form a sense

of belonging to their region and country. The influence of media and information policy on citizens' perception of their identity is examined. The study examines the impact of digitalization and the spread of information technology on the formation of civic identity, especially among young people. Digitalization and the spread of information technology have a significant impact on the formation of civic identity in Kyrgyzstan. Social networks and digital platforms are becoming the main channels for communication and information exchange, contributing to the formation of a new digital civic identity (Abdiev, 2022). At the same time, information wars and fake news can negatively affect the perception of public policy and social unity.

State information policy and the media play an important role in shaping public opinion and civic identity. Television and internet programs aimed at promoting state symbols and national heroes contribute to the formation of patriotic sentiments among the population (Usubaliev, 2020). However, the lack of a balanced information policy can exacerbate social divisions, especially among young people. Ethnocultural education in schools and universities in Kyrgyzstan plays an important role in strengthening civic identity. Programs that include the study of the cultural heritage of various ethnic groups living in the country contribute to the formation of respect for diversity and the strengthening of civic identity (Toktomushev, 2021). However, limited resources and weak methodological support for these programs often lead to their low effectiveness, which requires a review of approaches and a strengthening of intercultural education.

Social policies aimed at supporting vulnerable groups, such as young people, women, and older citizens, also contribute to the formation of civic identity (Kenzhebaeva, 2019). Social protection and labor integration programs strengthen citizens' sense of belonging and participation in public life, creating conditions for the equal participation of all members of society. This section discusses the key stages in the development of public policy in Kyrgyzstan and their impact on civic identity. It examines policies towards migrants and their impact on the processes of forming a common civic identity. Kyrgyzstan's legal policy has a direct impact on the formation of civic identity, especially through the development of legal norms regulating civil rights and obligations. Constitutional changes and reforms in the field of human rights contribute to the formation of a legal culture and the strengthening of civic responsibility (Osmonov, 2020). Laws protecting freedom of speech, assembly, and other civil liberties are important elements that contribute to the strengthening of identity based on citizenship rather than ethnicity.

Migration processes in Kyrgyzstan play an important role in the dynamics of civic identity. State policy towards internal and external migrants is aimed at their social and economic integration, which in turn influences overall civic identity (Ivashchenko, 2022). Programs to support migrants and involve them in socially significant projects help to strengthen their sense of belonging to Kyrgyzstan, despite ethnic and cultural differences. Analysis of the influence of political rhetoric and state symbols on the perception of civic identity among the population. Political rhetoric and the use of state symbols, such as the flag and coat of arms of Kyrgyzstan, play a key role in shaping civic identity. Official speeches and mass events emphasize the country's common values and historical unity, which helps to strengthen civic identity (Zhakupova, 2020). However, the use of rhetoric aimed at highlighting ethnic or regional characteristics can lead to the fragmentation of society and a decline in civic integration.

Since gaining independence in 1991, Kyrgyzstan's public policy has undergone significant changes, including reforms in the educational, linguistic, and cultural spheres aimed at strengthening civic identity (Megoran, 2013). The introduction of new laws, such as the Law on State Language Policy, has played an important role in shaping a civic identity based on shared values rather than ethnicity (Laruelle, 2020). Kyrgyzstan's cultural policy, focused on preserving historical and cultural heritage, plays an important role in strengthening civic identity. State programs for the restoration of monuments, support for traditional crafts, and the organization of national festivals contribute to citizens' awareness of their role in the country's history and strengthen their sense of national pride (Asanov, 2018). However, insufficient funding and weak coordination of these initiatives may limit their impact. This section analyzes current challenges and the impact of state policy on civic identity. Contemporary state policy in Kyrgyzstan faces challenges related to regional and ethnic differences. Integration policies aimed at strengthening national identity often face resistance in regions with ethnic minority populations (Marat, 2018). Successful public policy must take these differences into account and promote intercultural dialogue.

Kyrgyzstan's religious policy is aimed at supporting a secular state while preserving freedom of religion. In the context of growing religious activity, especially among young people, state policy should be aimed at preventing religious radicalism and supporting interfaith dialogue (Ismailov, 2020). The balance between secular and religious values is an important element in the process of forming civic identity, which helps to avoid the division of society on religious grounds. Research on the impact of international politics and Kyrgyzstan's participation in regional and global integration processes on the formation of civic identity. Kyrgyzstan's participation in international and regional organizations such as the Shanghai Cooperation Organization (SCO) and the Eurasian Economic Union (EAEU) influences the processes of civic identity formation. International politics and integration processes open up new opportunities for economic development and cultural exchange, which contributes to the formation of an identity based on an awareness of one's place in the global community (Baizakov, 2022). However, the impact of international sanctions or political pressure can also provoke resistance and a rise in nationalist sentiments. External migration and the active role of the Kyrgy' diaspora abroad have a significant impact on the formation of civic identity both within the country and among compat'Iots outside its borders.

Economic and social ties with migrants, as well as cultural exchanges through diasporas,'create a new form of civic identity that transcends national borders (Baiturova, 2020). However, the lack of a systematic state policy towards the diaspora can lead to a weakening of migrants' ties to their homeland and a decline in civic loyalty.

Educational reforms in Kyrgyzstan aim to strengthen civic identity by incorporating elements into the curriculum that promote national self-awareness and respect for cultural diversity. The introduction of courses on the history and culture of Kyrgyzstan, as well as the implementation of patriotic education programs, contributes to the formation of an identity based on civic rather than ethnic characteristics (Toktogulov, 2021). At the same time, the lack of resources and professional training for teachers remains a significant obstacle to the effective implementation of these reforms. Analysis of education policy as a tool for shaping civic identity. The education system plays an important role in shaping civic identity by including subjects in the curriculum that focus on the study of history, culture, and national values (Kapushev, 2015). Patriotic education programs help strengthen feelings of belonging to the state and understanding of the role of citizens in society. Kyrgyzstan's gender policy also plays a significant role in the process of forming civic identity, especially in the context of strengthening equality and integrating women into public life. Programs to support women, gender education, and the protection of women's rights contribute to the formation of an inclusive civic identity, where all citizens have equal opportunities to participate in public and political life (Tilekova, 2018). At the same time, patriarchal traditions and gender stereotypes continue to create barriers to full equality. This section explores how political instability and economic and social crises affect civic identity in Kyrgyzstan. Political instability and economic crises in Kyrgyzstan often lead to a weakening of civic identity. Coups, protests, and economic difficulties create conditions for social fragmentation and the strengthening of ethnic and regional identities at the expense of civic identity (Jorobekova, 2019). In such conditions, state policies aimed at restoring trust and ensuring social justice play a key role in strengthening civic identity. Research on internal migration processes, such as labor migration from regions to cities, and their impact on civic identity.

Internal migration in Kyrgyzstan, especially from rural areas to the capital and major cities, has a significant impact on civic identity. Faced with new living conditions and cultural challenges, migrant workers often experience an identity crisis, balancing between traditional rural values and urban realities (Saralaeva, 2022). State support for migrants through social programs and adaptation courses can contribute to more harmonious integration and the strengthening of civic identity. Analysis of the impact of public holidays, celebrations, and symbols on the formation and strengthening of civic identity. Public holidays and symbols play an important role in shaping civic identity, creating a sense of unity and belonging to the nation. Celebrating events such as Independence Day and Constitution Day helps to strengthen patriotic feelings and citizens' awareness of their role in society (Akylbekov, 2018). The introduction of new traditions and state events, such as cultural festivals, can further contribute to social cohesion.

Conclusion

The conclusion summarizes and draws conclusions about the role of public policy in shaping civic identity. The findings of the study emphasize the need to align public policy with the realities of Kyrgyzstan's multinational society. Summarizing the findings of the study, it emphasizes the need for a comprehensive approach to public policy that takes into account both traditional and modern aspects of the formation of civic identity. Kyrgyzstan's public policy has a multifaceted impact on the processes of civic identity formation, including legal, gender, religious, and international aspects. To successfully strengthen civic identity, it is necessary to continue improving policies aimed at integrating all segments of society, respecting rights and freedoms, and supporting interethnic and intercultural dialogue. The impact of public policy on the formation of civic identity in Kyrgyzstan is multifaceted and requires a balanced approach that includes economic, social, cultural, and digital aspects. To achieve sustainable development, it is necessary to continue integrating different ethnic and cultural groups based on common civic values supported by public policy. Government policy in Kyrgyzstan has a significant impact on the formation of civic identity, but its success depends on a comprehensive approach that includes consideration of ethnic diversity, support for integration programs, and the development of educational initiatives. It is important to continue improving state policy aimed at strengthening civic identity, based on the principles of respect, equality, and interaction.

State policy plays a critical role in shaping civic identity in Kyrgyzstan, influencing various aspects of public life, including education, culture, and legislation. For the successful development of civic identity, it is necessary to continue to support and develop policies aimed at strengthening unity and national self-awareness. State policy has a significant impact on the processes of shaping civic identity in Kyrgyzstan, covering various aspects of social, cultural, and political life. To achieve sustainable results, it is necessary to continuously improve policies aimed at supporting ethnic and cultural diversity, strengthening patriotism, and promoting social integration.

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PSYCHOLOGICAL SCIENCES

AITMATOV AND RELIGION

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Abstract

The article examines the religious and philosophical dimension of Chingiz Aitmatov's work in the context of the transformations of public consciousness in the post-Soviet period. It analyzes the writer's views on religion, his interpretation of Islamic and Christian traditions, as well as the artistic representation of biblical and Koranic motifs in the works "The Scaffold," "And the Day Lasts Longer Than a Century," "The Mark of Cassandra," and "When Mountains Fall." Particular attention is paid to the problem of the relationship between secular humanism and religious ethics, as well as the author's position on issues of religious revival, extremism, and the spiritual crisis of modernity. The methodological basis of the study consists of the principles of historical-literary, comparative-typological, and hermeneutic analysis. The conclusion is made that Aitmatov's religiosity is universalist and humanistic in nature and is oriented toward the integration of universal human values rather than confessional isolation.

Keywords: Chingiz Aitmatov, religion, Islam, Christianity, humanism, mankurtism, spiritual crisis, post-Soviet society, intercultural dialogue.

"I like studying Islam in Muslim countries and Christianity in European countries;
I immerse myself in them as one immerses oneself in culture.
Here, I agree with Goethe: 'He who knows only one
religion knows none at all. Artificial religious narrow-mindedness
does not lead a person to the truth, but away from it."
Chingiz Aitmatov

UNESCO data attests to the worldwide recognition of the works of the outstanding writer Chingiz Aitmatov in world literature: on the eve of the 21st century, Aitmatov's books had been published 830 times in 168 countries, with 67.2 million copies in 165 languages. According to the latest UNESCO data, Ch. Aitmatov is named the most widely read writer in the world after W. Shakespeare and L. Tolstoy. His books have been translated into 176 languages and published in a total circulation of 80 million copies. Our famous compatriot is not only an outstanding writer, philosopher, and public figure, but also a man who told the world about the Kyrgyz people and Kyrgyzstan.

And the more time passes without Aitmatov, the more his greatness and the significance of his immortal works, which will continue to educate many generations of young people for a long time to come, become apparent. Reviews of him and his work, regardless of who wrote them, recognize him as a brilliant writer, thinker, and artist of the literary word, embodying the power of human intellect, immortality, and internationalism.

Over the past half-century, a huge number of serious works have been written about Aitmatov's work, his philosophy of life, his social problems, his artistic images, and contradictions. Today, there is a whole scientific field in world literary studies called Aitmatov studies. Today, there is an entire academic field in world literary studies known as Aitmatology. In this context, we are interested in the question of the writer's attitude toward religion, which is not only dynamically reviving in modern conditions, but has also become a noticeable phenomenon in the socio-cultural life of the country, the essence of which lies in an ill-considered leap from one extreme to another. Thus, if during the Soviet era, under totalitarian atheistic pressure, religion was expelled from all spheres of public life, eradicated everywhere, with only a few traditional rituals being tolerated, without which Kyrgyz life was essentially impossible (nike, janaza, sunnot, etc.), in the post-Soviet

period, the ideological void was quickly filled with religious ideology, unfortunately, preferably archaic, pulling society backward. On the one hand, many Muslims gained the opportunity to openly live according to the canons of Islam: to receive religious education, observe all rituals, eat halal food, raise children in the Islamic spirit, perform the hajj to Mecca, etc. In other words, Islam, as the religion of the country's majority population, has taken root in many areas of public and private life. Religious prayers for Kurman and Oroz Ait began to be held in central squares with the participation of top government officials. There were noticeable processes of increasing religious awareness, non-alcoholic events began to be held more and more often, and the appearance of both people and villages and cities changed—numerous domed mosques and religious educational institutions were built with funds from foreign and local sponsors. At the same time, destructive phenomena previously unknown appeared, such as religious extremism, radicalization, the politicization of Islam, the claims of Islamic religious organizations to power, their increased involvement in political processes, and much more, causing concern among society and the state.

Undoubtedly, Aitmatov was not indifferent to the processes taking place and asked himself questions: "... I reflect myself, to the best of my ability, on what religion is. To what extent should we devote ourselves to religion? To what extent can we trust it?" [1] Distressed by this, in one of his interviews he said: "...the crisis of religious consciousness... has already begun. I realized this recently when a man who had converted from Islam to another faith died in a village in Kyrgyzstan, and his relatives, who were carrying him to the cemetery, were blocked by a frenzied, angry crowd of local Muslims. The relatives had to take the deceased hundreds of kilometers away to bury him there. If we cannot give way to each other in front of the cemetery, what can we say about life?"

At the same time, he repeatedly repeats the idea in his numerous interviews that "we must distinguish between the great religion of Islam and the people who profess it." He says: "Religion is great in itself. Its greatness can be seen through the prism of the universal development of humanity. How many countries in this world have been destroyed, turned to ashes, how many civilizations have completely disappeared from the face of the earth. Eras and times have changed in the world, but religion has not been erased from the human heart. This is the great value of religion. In religion, we seek the mysteries of man and the universe; in religion, we seek the great power capable of purifying our spiritual universe.

It is well known that the functions of religion and literature are similar in addressing issues of morality and education, in creating and perfecting human nature. According to the writer, literature should have such value orientations as understanding human nature "...so that the eternally great immortal passions constantly prevail in it: creation, continuation, and preservation of the human race, man's knowledge of himself and his purpose in life. For only in this case, if we manage to withstand the destructive forces of inhumanity and immorality, preserving and elevating the spirit of humanism - only in this case does man define his name as a thinking being." Therefore, in all of the writer's works, the story of the moral collapse of man is condemned ("My Topolek in a Red Kerchief"), Duishen fights against the inertia of social prejudices ("My First Teacher"), extols the best qualities of the human personality such as decency, honesty, truthfulness, justice, protest against the lies and cruelty of the 'adult' world (in "The White Steamboat"), the weakness of human will, betrayal (in "Ascent to Fuji"), etc.

What are the consequences of the revival of religious life, what fruits will we reap from it, what will we ultimately achieve? Why have negative phenomena such as irresponsibility, corruption, child abuse, neglect of the elderly, deception, and ignorance overwhelmed society? Without a doubt, the writer was concerned with the question of why, despite the dynamic process of Islamization, morality, ethics, and purity of thought are in deep crisis.

What is the reason why religion is failing to fulfill its main social function—spiritual and moral revival? After all, it is in religion that the universal spiritual and moral values, proven by thousands of years of life experience, are concentrated. These and many other questions preoccupied Aitmatov, who was not indifferent to the future of his people. The tragedy of the transformations that took place is vividly reflected in his last work, When the Mountains Fall, despite the fact that questions of religion are not raised in it; however, the author is deeply concerned about the changes that have taken place in the spiritual impoverishment of society.

In his novel "The Day Lasts More Than a Hundred Years", the writer showed that a person deprived of higher reason becomes a mankurts, who will not even stop at murdering his mother, the woman who gave birth to him. "If before, people who were zombies, mankurts deprived of reason, were the heroes of my work, now they have turned into real people. How else can we call those who, in different corners of the world today, carry out terrorist acts against people, often without even sparing themselves?"

The writer's planetary thinking is reflected in the novel "And the Day Lasts Longer Than a Century," in which earthly events intersect with cosmic ones; extraterrestrial cosmic forces respond to people's evil and good deeds. The quintessence of "The Gallows" is the idea of the contradictory nature of human beings: on the one hand, humans subjugate and exploit nature, and on the other hand, they destroy it with their transformations. This idea is continued in "The Mark of Cassandra," where a scientific experiment to create an artificial human turns into a personal tragedy for the scientist, who realizes the monstrous nature of violence against nature, which can lead to a global catastrophe. The writer attempts to answer questions about the relationship between humans and religion. In the story "The White Cloud of Genghis Khan," while the conqueror is doing earthly deeds, the heavens favor him, but as soon as he begins to do evil, the cloud, which in the religions of many peoples symbolizes purity and the divine, deprives Genghis Khan of its support.

There is a well-known statement by the writer's daughter, Shirin Aitmatova, who, while serving as a member of the Kyrgyz parliament, during a discussion of a bill requiring the president to take an oath (vow) before God, spoke out against it, stating that my father, Aitmatov, was a convinced atheist: “This does not mean that this man was a bad person” [2]

Undoubtedly, as a prominent representative of the Soviet generation, Ch. Aitmatov had a secular worldview. That is why all of Ch. Aitmatov's works—short stories, novellas, novels, essays, articles, and dialogues—raise simple but eternal moral issues. In them, the writer fiercely denounces evil, treachery, baseness, power-hunger, and tyranny, while at the same time extolling in his characters freedom of thought, the irreconcilable struggle between good and evil, exalting justice and people possessing the highest qualities of human conscience, elevating to divine holiness heroic natures whose heroism lay in the nobility of their deeds and in their purity. His works make the reader experience the meaning of human life and conscience, and think and reflect on what a real person should be like and what their highest purpose is.

As a humanist, the writer endows his contemporaries with such human qualities as “the ability and skill to think at the level of advanced, progressive ideas, to think globally, which is, in essence, genuine internationalism, genuine respect for the uniqueness of cultures, national languages, art, and values developed by all peoples.” And, finally, it is the ability to think ahead, discerning today the trends of tomorrow. [3]

At the same time, an analysis of the great writer's works in terms of his attitude toward religion shows that his creative work was based on universal humanistic values, which largely correspond to the values of world religions.

In his work “The Cross,” the writer, through his character he asked the question: “Have you ever heard of an elderly person who has experienced considerable suffering in life losing faith in God at the end of their life or interpreting divine concepts in their own way? No, if such a thing happens, it is undoubtedly extremely rare”. [4 p.50]

As we get to know the works of this great writer, we see that he was familiar with religious values and mythology and had a thorough understanding of the world's religions and sacred writings. Therefore, in his works, the writer uses ancient myths, biblical motifs, and contemporary philosophy.

The novel “The Scaffold” explores the theme of Jesus Christ, although his name is not mentioned, but there are references to “the Galilean,” Pontius Pilate, and Bald Mountain, and an educated reader understands that this is a reference to a well-known episode from the Gospel. Aitmatov's Christ in his novel is a collective image of a moral man, and the apocalypse - the end of the world - “comes from the enmity of people,” says the writer through the words of his character Avdiya. Living mentally in several temporal incarnations, Avdiy implores people not to allow Christ to be executed. In the hero's memory, there is a great unity of being: it consists in the fact that “good and evil are passed down from generation to generation, in the infinity of time and space of the human world.”

Regarding the role and place of Islam in society, the writer noted: "Islam, in my opinion, like other religions, should occupy an appropriate place in the lives of believers, but in no case should it serve as a reason for isolation from others and, even more so, should it not give rise to conflicts. Its task is to uphold and preach unshakable truths."[5]

Speaking in Moscow in 2005 at the conference “Islam - Religion of Peace,” Chyngyz Torokulovich noted: "A provocative campaign is being waged against Islam in the world today, portraying it as an enemy of world civilization. In light of what is happening in the world, I wonder whether the fight against international terrorism is not a total war against the peaceful coexistence of people? Why is Islam being blamed for international terrorism? This is a cunning provocation against the Muslim religion. But the point today is not even that we must defend Islam with all our might against various attacks, because as a great religion, it does not need this. The problem, in my opinion, lies with Muslims themselves, especially religious leaders, who, despite often having high theological qualifications, are not yet able to convince the whole world that Islam has nothing to do with terrorist. Unfortunately, the latter fiercely exploit the Muslim religion, thereby discrediting it. As a result, the world is overwhelmed by tension, one of the main sources of which is poverty and illiteracy, which prevail across vast areas of the globe. Wars are breaking out, which are, in fact, even more terrible than terrorism. The very essence of human rights is being eroded. Conflict between East and West has become an inevitable reality. These problems must also be addressed. That is why it is more important than ever for both sides, in the West and in the East, to adopt a reasonable approach and understanding of what is happening, which would facilitate cooperation between all healthy forces. It is necessary to change the situation where poverty and prosperity, which divide the East and the West, constantly give rise to new social upheavals. In my opinion, this is what we need to talk about more and more now in order to overcome existing problems without revolutions, riots, and bloodshed. [6]

He believed that it should be understood that the negative attitude towards Islam in today's world, especially on the part of the West, is largely shaped by Muslims themselves: "It is one thing when modern, educated young Europeans who know several languages discuss the divine, the Koran, and Islam. It is quite another when a shepherd, even if he is an honest, kind, and decent person, but whose understanding of the world is extremely limited, does so. In general, we must realize our responsibility to the future, develop ourselves, and be creators. Today, as a result of globalization, everything that was closed, isolated, or excluded is opening up and becoming accessible. At the same time, the West, with its greatest achievements in virtually all areas of life, feels itself to be the dominant force. The Islamic world lags behind, sometimes even trying to isolate itself from global trends. But the path to prosperity lies precisely in overcoming this, frankly, huge gap, in acquiring the ability to enjoy the benefits of

modern civilization. We must join in global development and become participants in world processes ourselves. Without this, it is impossible to regain a leading position in the world. Meanwhile, as we integrate, we must not forget our own identity. After all, this is the art of living."

When reporters asked him questions on this topic, he said that he planned to write a novel using Muslim themes. At the same time, he noted that he would leave the choice up to the reader and would not "... impose any ideas on the reader, and at the same time, not give any reason to desecrate Islam. I also hope that among the new generation of the Islamic world, there will be those who, being passionate about religion, will be able to express the spirit of their time, their experiences, and ideas, basing their creativity on the Koran."

In response to a question from the People's Writer of the Kyrgyz Republic, playwright S. Raev, about how many people in the world today see reading the Bible and the Koran as a way out of spiritual poverty, and how all the great writers, from Goethe, Dostoevsky, Tolstoy, T. Mann, and Bulgakov, having reached the pinnacle of their creative development as writers, turned to the "search for God," how do you feel about this? The writer replied: "Both the Koran and the Bible are aimed at purifying the human soul, at showing it all the existing paths of development. In this sense, true literature is in harmony with the Great Words, bringing their meaning to the world... Religion is great in itself. Its greatness can be seen through the prism of the universal development of humanity.

In our opinion, the writer's attitude toward religion is expressed in the words of his character, the futurologist Bork: "...perhaps the time has come, a historical era when all religions could come together to meet humanity, rather than separately and jostling each other? So that a person at the end of the twentieth century could declare, unlike previous generations, 'All religions are mine, and I am the bearer of all religions, I am welcome in all temples of all cults, and in all temples I am a welcome pilgrim... I was born to Christians, I was baptized, and I will be buried to verses from the Koran. Today I was Orthodox with the Orthodox, yesterday I was a Muslim among Muslims, in Japan I worshipped Buddha, in Sweden I echoed Luther's theses. I am no stranger to anyone in my faith in God, and I am no stranger to the prayers that people offer to our Creator in all languages and dialects. The Creator, who listens to us all equally, suffers equally from our misdeeds, and opens the universe to us all equally, according to our wisdom and virtue... Religion, as Aitmatov understood it, was not only a system of beliefs, but also a deep layer of human culture, a moral support, and a form of spiritual search. At the same time, the writer was critical of manifestations of fanaticism, the politicization of faith, and its instrumentalization for ideological purposes. Thus, religious issues in Aitmatov's legacy are not reduced to confessional affiliation, but appear as a form of philosophical reflection on the fate of man and humanity in an era of global challenges.

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RELIGIOUS IDENTITY AND PERSONALITY DEVELOPMENT IN ADOLESCENCE

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Abstract

Adolescence is one of the stages of development that plays an important role in the formation of human personality. During this period, individuals not only assimilate social roles and values, but also try to determine their own moral and worldview position, their own social and spiritual identities. Religious identity, as one of these forms of identity, also affects the formation of an individual's value system and worldview. The aim of the article is to analyze the socio-psychological essence of religious identity in adolescence, the theoretical content of the concept of religious identity, the mechanisms of its formation and the role of the personality in self-consciousness on the basis of scientific literature. The study was carried out using the qualitative analysis method based not on the collection of empirical data, but on the systematic study of existing psychological and sociological literature. The article considers religious identity as a complex socio-psychological phenomenon related to the individual's religious beliefs, moral values and sense of religious belonging. The theoretical analysis shows that religious identity can play an important role in the development of adolescents' self-awareness, the formation of a value system and the understanding of the meaning of life. As a result, religious identity acts as one of the important components of the personality structure during adolescence and can be considered one of the important factors affecting the spiritual and psychological development of the individual.

Keywords: Adolescence, religious identity, personality development, social environment, spiritual values.

INTRODUCTION. Relevance of the topic. In modern psychological research, adolescence is considered one of the most important stages of personality formation. During this period, the individual goes through the process of self-awareness, determining his position in the system of social relations and forming various identity components. Psychological and social changes occurring during adolescence have a significant impact on the formation of an individual's value system, worldview and behavioral directions.

In modern society, socio-cultural transformations, globalization processes and the interaction of various value systems are giving new directions to the identity formation of adolescents. In this context, religious identity attracts attention as one of the socio-psychological components that play an important role in the process of individual self-identification. Religious identity is a complex form of identity that reflects not only the adoption of religious beliefs, but also the individual's attitude to spiritual values, the process of making sense of life, and social behavior models.

In this regard, the study of the characteristics of the formation of religious identity in adolescence and its interaction with personality development is one of the current scientific problems for modern psychological research.

Scientific and practical significance of the topic. The study of the relationship of religious identity with the personality development of adolescents is important both theoretically and practically. From a theoretical point of view, this study can contribute to a deeper understanding of the mechanisms of formation of religious identity in adolescence within the framework of identity theories and developmental psychology.

From a practical point of view, the study of the impact of religious identity on the psychological development of adolescents can provide an opportunity to obtain important results that can be applied in educational institutions, in psychological and social work with young people, as well as in the upbringing process.

Problem statement and research gap. In modern scientific literature, the topic of religious identity has been studied from various aspects. The impact of religious identity on an individual's social behavior, moral values, and life position has been widely discussed in studies. However, most of the existing studies have used quantitative methods in studying religious identity.

As a result, in-depth research on adolescents' personal experiences with religious identity, how they perceive religious beliefs, and what meaning these beliefs give to personality formation has remained somewhat limited. Studying adolescents' subjective experiences and meaning-making processes regarding religious identity necessitates the application of qualitative research methods.

In this regard, investigating the characteristics of religious identity formation during adolescence in the context of individuals' personal experiences is of particular importance in terms of eliminating the existing research gap.

Purpose of the study. The main purpose of the study is to investigate the characteristics of religious identity formation during adolescence and its relationship with personality development based on the qualitative analysis method.

Scientific novelty of the study. Unlike existing studies, this study does not only measure religious identity, but also examines adolescents' subjective experiences with religious identity and their The meanings

they give to religious identity are analyzed. Within the framework of the study, the individual experiences of adolescents regarding their religious identity and the role this identity plays in their personality development process were determined. At the same time, the interaction of religious identity with social and psychological factors in the process of adolescents' self-identification was systematized on the basis of qualitative analysis.

Research questions. In accordance with the purpose of the study, the following research questions were put forward:

How do adolescents perceive religious identity and how do they perceive it as part of their identity?

In what way do religious values affect the process of adolescent personality development?

The concept of identity is considered a person's ability to understand himself. The concept of identity is expressed in English as “identity”, and in Latin as “identitas”. According to I. Zargan in his work “Man, Identity and Identification”, the concept of identity expresses the self-awareness of the individual, self-perception, the ability to adapt to social society, and the assessment of one's own potential (Zargan, n.d). Identity is a unique, different, and unrepeatable state of balance that stands out from the crowd (Bayramov & Alizadeh, 2009).

Based on the approaches and relevant ideas of representatives of modern psychology on the study of identity, these approaches look at the issue of studying personality from different perspectives. These theoretical approaches complement each other and do not contradict each other, take into account different aspects of the identity phenomenon and create an opportunity to better study personality. Social identity is related to both personal identity and social processes (Waterman, 1985).

The concept of religious identity is accepted in modern psychology as one of the structural elements of personality and plays an important role in the individual's self-awareness, the formation of his worldview, the system of social relations and behavioral strategies. Religious identity is valued not only as a set of beliefs, but also as a key component of a person's understanding of himself and the world, and determining his goals and directions in life.

In psychological approaches, religious beliefs are presented as an important mechanism in regulating human behavior and forming a spiritual and moral system. From this perspective, religious identity is formed in an environment of interaction between internal and external factors that affect the development of an individual's personality and acts as a stable and enduring component in the structure of the personality. Studies show that religious values and beliefs determine the meaning an individual gives to life events, the ability to self-regulate in difficult situations, and psychological resilience. Thus, religious identity is not only a part of the spiritual system, but also a psychological mechanism that plays an important role in the social and emotional adaptation of the personality (Jensen, 2021).

Religious identity is also crucial in establishing an individual's relationships with the social environment and integrating them into the cultural values of society. It shapes how a person perceives himself in a social context and how he behaves based on this perception. This process strengthens self-awareness and self-concept at the individual level, and determines the structure of mutual relations and social participation at the social level (Nechyporenko et al., 2019).

Religious identity, as one of the main structural components of an individual's self-system, plays an important role in the formation of his worldview, self-awareness and psychological health. In addition to providing a person with deep ideas about the meaning of life, it acts as a source of social support and moral support, and at the same time strengthens the fight against stress and emotional resilience (Ayub et al., 2022).

Leicht et al. (2021) showed that the content of religious doctrines directly shapes attitudes towards science and technology. More stringent religious rules result in a cautious and critical approach to scientific innovations (Leicht et al., 2021). These ideas are also consistent with the study of Alkhouri (2024); he analyzed the impact of artificial intelligence on religious identity and emphasized that technological changes are reshaping people's understanding of faith (Alkhouri, 2024).

According to Schmees and colleagues (2024), religious discrimination manifests itself in various forms and the social exclusion of religious minorities negatively affects emotional and physical health (Schmees et al., 2024). These results are also confirmed by the study of Veerasamy et al. (2023): religious experiences reduce stress, enhance emotional well-being and increase life satisfaction. However, the attitude towards religion in psychology is still not unanimous (Veerasamy et al., 2023). Sharkey (2022) emphasized that religious identity affects human self-determination at both the internal (beliefs) and external (social environment) levels. All these studies highlight the multifaceted nature of religious identity and the ten Religion plays a major role in shaping adolescent behavior. Given the importance of religion, researchers have examined how religious identity develops. Religious identity is the meaning people give to their religious group membership, which in turn influences their sense of belonging (Arweck & Nesbitt, 2010).

Religious affiliation is influenced by factors such as generational status, ethnicity, and gender (King & Boyatzis, 2004). Religious identity is shaped by the devotional, social, psychological, and political aspects of religious affiliation (Deaux, 2001).

Religious identity is a set of affiliations, beliefs, and experiences that are determined by various factors. Research has shown that the most important part of religious identity is the belief system. The essence of religious identity is belief, which, if well-embedded, leads to appropriate religious behavior and religious commitment (Copen & Silverstein, 2008).

Parents are an important determinant of religious identity. Parents have a great influence on individuals' religious ideologies (Yi et al., 2004). Parents have left lasting marks on their children's religious commitments

and ideologies (Bengtson, 2001). Parents have an important role in children's participation in religious activities and the formation of faith identity. For parents, transmitting their beliefs to their children is part of their parental responsibilities (Horwath et al., 2008).

Religious identity is one of the most relevant research areas in modern psychology and social sciences. This concept expresses a person's conscious understanding of his or her relationship with spiritual values, religious beliefs, and the religious community to which he or she belongs. Adolescence is considered the most sensitive and dynamic stage for the formation of this identity. At this stage, a young individual begins a search to find his or her "self", understand the meaning of life, and determine a value system. Religious identity emerges as part of these psychosocial searches and plays an important role in the integration of the adolescent's personality. According to Erik Erikson's (1968) theory of psychosocial development, identity formation is a lifelong process, but its main stage occurs during adolescence. Erikson considers religious identity as a component of the overall "self" structure and notes that religious affiliation gives the adolescent both moral stability and social orientation. In his opinion, the assimilation of values and the establishment of a belief system are key factors in the integration of personality (Erikson, 1968).

Fowler (1981) has shown that religious belief and identity develop in stages. The adolescence stage is the main stage when a person consciously realizes his religious identity (Fowler, 1981).

Modern psychological and sociological research shows that religious identity plays an important role in the spiritual development of adolescents, the formation of social relationships, and the determination of life goals. Smith and Denton's (2005) study "Soul Searching" shows that parents' religious practices and beliefs directly determine adolescents' religious orientation. The family model plays the role of both moral guidance and behavioral role model. At the same time, in modern times, social media, cultural globalization, and ideas of individual freedom create flexible and multi-level forms of religious identity in young people (Smith & Denton, 2005).

Adolescence is considered one of the most important developmental stages in human life. This stage is characterized by the growth of the individual, self-awareness, and the formation of his or her identity. The messages that adolescents receive from the cultural environment they belong to—through the media, peer groups, and other social influences—create an idea of what behaviors they should exhibit and what ideals they should strive for, and this significantly affects the formation of personality, as well as psychological well-being (Stryker & Burke, 2000).

After the childhood stage ends, a completely new stage of development begins in human life, which is different from previous periods, and this stage is called adolescence (Bayramov & Alizadeh, 2003). According to psychologists, over time, due to the diversity of the period, adolescents develop extreme and instinctive tendencies, special mental and psychological feelings, which intensify their direction towards religious and moral issues. Family, friends, school, social environment and other related factors can create spiritual evolution and mature ideas in adolescents, as well as lead them to the right path. Thus, over time and over the next many years, that person will make changes in their religious, spiritual and social identity and personality, their behaviors such as evil, suffering, greed, suffering, stress, theft and lying will decrease and be eliminated, and the adolescent will be directed towards the path of religion and human morality (Bayram ov, 1981).

Adolescence is characterized in psychology as a transitional or "crisis" stage, which is not accidental. Factors such as psychophysiological renewals, changes in the system of relationships, and differences in the perspective of oneself and others that occur at this stage reshape the behavior and attitude of the teenager, have a strong impact on the perception of new potential opportunities and individual characteristics in his "I" concept. These factors create conditions for determining the teenager's identity, directing his ideas and desires in a specific direction. In such conditions, fundamental questions such as "Who am I?", "What will my life path be like?", "Where will my future lead me?" arise in the teenager's mind, which also prompt him to think deeply and search for answers. At this age, young people carefully analyze problems, make decisions after weighing them, and do not easily compromise their adherence to their religious beliefs. If they observe a difference of opinion or practical inconsistency in the matter of religion, they react in two ways: if their faith is weak, this situation undermines their faith, otherwise they raise their voices of protest and demand that the principles of the religion be followed in all matters (Aliyev & Jabbarov, n.d).

Religious identity is one of the most relevant research directions in modern psychology and social sciences. This concept expresses a conscious understanding of a person's relationship with spiritual values, religious beliefs and the religious community to which he belongs. Adolescence is considered the most sensitive and dynamic stage for the formation of this identity. At this stage, a young individual enters into a search for his "self", understanding the meaning of life and defining a system of values. Religious identity emerges as part of these psychosocial searches and plays an important role in the integration of the adolescent's personality (Erikson, 1968).

Methodology. In this study, a qualitative research approach was applied to investigate the issue of religious identity and personality development during adolescence. The methodological basis of the study is the analysis and comparison of various scientific approaches explaining the psychological and social aspects of religious identity. In the research process, the main focus was on the systematic study and analytical analysis of the existing scientific literature on the topic.

Research design. The design of the study is based on the analytical study of scientific sources on the topic. The main goal of the study was to systematize the theoretical approaches put forward by various researchers on religious identity and personality development during adolescence and to summarize their main content. This approach allows for a clearer understanding of the

psychological, social and cultural factors that affect the formation of religious identity. Within the framework of the study, both classical and modern scientific studies conducted on identity, religious identity and the psychological characteristics of adolescence were reviewed. In this context, Erik Erikson's theory of psychosocial development, Fowler's model of the stages of development of religious belief, as well as modern psychological approaches based on the theory of social identity formed the methodological basis of the study.

Data sources and selection principle. The main database of the study consists of scientific articles, monographs and studies published in international scientific journals published in different years. Several main criteria were taken into account when selecting the literature: the sources should be directly related to the topic of religious identity and personality development during adolescence; have scientific reliability and be published in academic publications; take into account modern research in addition to classical theoretical approaches. Based on these criteria, the works of Erikson, Fowler, Smith and Denton, Jensen, Veerasamy, Schmees and other researchers were selected as research material. These sources were analyzed in terms of the psychological content of religious identity, its interaction with the social environment and its impact on the personality development of adolescents.

Analysis procedure. The scientific sources selected within the framework of the study were analyzed using the qualitative content analysis method. The analysis process consists of several stages. In the first stage, the main theoretical approaches to the topic were identified and scientific ideas about religious identity, social identity and the characteristics of adolescence were reviewed in a general way. In the next stage, the data obtained were grouped in terms of content. This includes issues such as the concept of identity and social identity, the psychological structure of religious identity, its interaction with the social environment, identity formation during adolescence, as well as the influence of family, school and social environment on this process. Then, the ideas put forward by various researchers are analyzed comparatively and their similarities and differences are identified. different aspects were identified. At the last stage, the results obtained were interpreted within the framework of psychological theories and the role of religious identity in the personality development of adolescents was summarized. The analyses conducted showed that religious identity is not limited only to the individual belief system, but is also a complex psychological process formed as a result of the interaction of family environment, social relations, cultural values, and personal life experiences.

Reliability and scientific substantiation of the study. In order to ensure the reliability of the study, the results of studies conducted in different countries and in different socio-cultural environments were reviewed and analyzed comparatively. This approach allowed us to more clearly identify both the general and contextual features of the process of religious identity formation.

In addition, the analysis of classical psychological theories together with the results of modern empirical studies created conditions for a more systematic study of the topic. As a result, the phenomenon of religious identity was evaluated not only as a theoretical concept, but also as one of the important factors affecting the social and psychological development of adolescents.

Conclusion. As a result of the qualitative analysis, it was determined that religious identity acts as one of the main psychological and social factors affecting the formation of personality during adolescence. As a result of a comparative study of various scientific sources on the subject, it became clear that religious identity should be considered not only as a concept expressing an individual's religious beliefs, but also as a complex psychological phenomenon related to his self-concept, value system and social relations.

Theoretical studies conducted within the framework of the study showed that the concept of identity has a broad and multifaceted meaning in psychology. In the approaches of various researchers, identity is associated with a person's self-awareness, determining his position in the social environment and assessing his individual capabilities. In this regard, it was determined that religious identity is considered one of the important elements of the general identity structure and is formed in close connection with a person's life goals, values and behavioral motives.

The results of the study show that adolescence is a particularly sensitive stage in terms of the formation of religious identity. It was determined that during this period the individual tries to understand himself more deeply, thinks about the meaning of life and begins to form a personal value system. According to Erikson's theory of psychosocial development, the most active stage of identity formation occurs precisely at this age. Therefore, religious beliefs and moral values can play an important role in determining the direction of a teenager's life.

As a result of the analysis of theoretical sources, it was determined that the development of religious identity is not limited only to individual choice, but is also closely related to the influence of the social environment. In particular, the family environment and the religious values of parents play an important role in this process.

As a result of the analysis, it was determined that during adolescence, an individual encounters various social influences and that these influences affect his attitude to religious values to a certain extent. In modern times, the widespread use of information technologies and social media is considered one of the factors that additionally affects the formation of religious identity in young people, and it was determined that these factors can lead to the formation of religious identity in a more flexible and multi-level manner.

Studies also show that religious identity is also to a certain extent related to the psychological well-being of adolescents. Religious beliefs in many cases play the role of spiritual support for a person, help maintain emotional stability in difficult life situations and strengthen the ability to cope with stress. In this regard, it has been determined that religious identity is evaluated not only as a system of spiritual values, but also as one of the factors supporting the social adaptation and psychological stability of adolescents.

Thus, the theoretical analysis conducted shows that religious identity is one of the important factors influencing the formation of personality during adolescence. Research conducted in this area allows for a deeper understanding of the psychological development, social behavior and value system of adolescents. At the same time, the results obtained in this direction can also be used as an important scientific basis for the development of social and pedagogical programs supporting the spiritual and psychological development of adolescents in the future.

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TECHNICAL SCIENCES

ANALYSIS OF THE EFFECTIVENESS OF NO-CODE SOLUTION ADOPTION IN CORPORATE INFRASTRUCTURE

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Abstract

The article examines the technological and economic aspects of adopting no-code solutions within corporate IT infrastructure. The study is based on an analysis of the performance, resilience, and integration capabilities of no-code platforms, as well as their impact on cost structures and return on investment. Quantitative assessments of adoption effects are presented using reports and empirical data demonstrating reductions in development time, lower maintenance costs, and accelerated digital transformation. The paper also explores organizational implications of no-code adoption, including the redistribution of roles between IT and business users, the growing importance of hybrid competencies, and the emergence of citizen development practices. The study concludes by substantiating the need for a comprehensive effectiveness assessment model that integrates technological metrics, economic indicators, and the specific context of corporate deployment.

Keywords: no-code, digital transformation, corporate IT infrastructure, performance, system architecture, development efficiency.

Introduction

In the context of rapid digital transformation of the business environment, companies increasingly face the need for accelerated implementation of IT solutions under constrained resources. One response to this challenge has been the growing adoption of no-code platforms – a technological approach that enables the creation of software products without traditional programming. Owing to graphical interfaces and modular architectures, no-code tools are gaining widespread popularity among both small businesses and large corporations seeking to enhance operational flexibility and reduce time-to-market.

The purpose of this study is to determine the economic and technological effects of implementing no-code solutions within corporate infrastructure. The analysis focuses on changes in key performance indicators, the time required for deploying IT solutions, as well as the resilience and reliability of systems developed using no-code approaches.

The relevance of the topic is driven by the increasing need for rapid digitalization of processes amid intense competition and continuously evolving market requirements. No-code solutions are examined as a means of balancing technological complexity with development accessibility, reducing the burden on IT departments, and democratizing the creation of digital products within organizations.

Main part. Concept and classification of no-code solutions

No-code is a technological approach to software development in which users are not required to possess knowledge of programming languages [9]. No-code platforms are based on visual builders, logical blocks, templates, and preconfigured integrations that enable the design of applications and the automation of business processes through drag-and-drop interfaces and configuration panels.

Within the analysis of no-code solutions, it is essential to distinguish them from conceptually related low-code platforms. Despite a shared focus on simplifying and accelerating software development processes, these approaches differ in the degree of reliance on programming and in the level of technical expertise expected from users. In particular, they vary with respect to flexibility, customization capabilities, and the complexity of solutions that can be effectively implemented (table 1).

Table 1

Comparative characteristics of no-code and low-code approaches [3, 6]

Criterion	No-code platforms	Low-code platforms
Role of source code	Generally, does not require end users to write any code; rather, functionalities are visually configured, while extensions can be made through built-in connectors/plugins or components that require administration/support staff assistance.	Code is typically used in such applications – often necessary in some ways – to perform complex logic, custom integrations, extensions, customization of screens, etc.
Typical user profile	Citizen developers (business users, domain experts, analysts, operations teams), usually within an IT-governed environment.	Software developers and technically trained analysts; may also include citizen developers under governance and guardrails.
Flexibility and customization	Constrained by the platform's available components, templates, and rules; the degree of flexibility depends on the platform ecosystem.	Generally higher due to support for custom code, reusable components, extensions, and advanced integration options.
Range of solution complexity	Suitable for standard business applications, business software, business automation, rapid prototyping – the complexity limit depends upon the constraints of the particular platform.	Better for complex business applications – complexity limit depends upon the architecture, engineering skills, and maintainability of the platform.
Required competencies	Minimal programming skills; strong domain/process knowledge is essential.	Depending on the complexity and extent of customization, integration, and non-functional features.
Typical use cases	Forms and apps for internal users, workflow automation, MVPs, quick digitalization of routine processes.	Enterprise apps and solutions, integration-rich solutions and apps, customizable and extensible solutions, and apps requiring non-standard logic and customization.

Among the existing no-code platforms, several classes of functionality can be isolated, which have differences related to the purpose of usage, abstraction level, and typical business scenarios of application in the corporate sphere. Among such broadly implemented classes of functionality, business automation platforms, such as Zapier, Make, n8n, etc., deserve particular attention. Next, there is a family of platforms dedicated to web application development, such as Bubble, Adalo, Glide, etc. For fast implementation of external business resources, there is a particular class of platforms dedicated to building websites and online shopping sites, such as Tilda, Webflow, Wix, etc. When talking about the application of no-code platforms in corporate structures, a particular role is played by a family of platforms related to development platform implementation, such as Microsoft Power Platform, AppSheet, Retool, etc. That is mainly due to their application for automation of processes within a corporation, development of interfaces in the field of data management, implementation of dashboards of business processes with visualization of performance.

Overall, no-code solutions address a broad range of tasks – from localized automation and integration scenarios to the development of applied systems that support business functions at the level of individual departments and processes. This makes no-code a practical instrument for accelerating the scaling of digital initiatives under conditions of limited IT resources, increasing pressure on development teams, and a high pace of change in the business environment.

Evaluation approaches to the effectiveness of no-code solution adoption

Assessing the effectiveness of no-code solution adoption requires a comprehensive approach that accounts for both technological and economic aspects of corporate IT infrastructure operations. In the context of growing demand for rapid digital product deployment and cost optimization, particular importance is attached to parameters such as business process performance, speed of functional implementation, system resilience to failures, and the integration capabilities of no-code platforms.

From a **technological perspective**, the effectiveness of no-code solution adoption should be assessed using a set of quantitative indicators that capture both the speed of digital function delivery and the stability and reliability of system operation in a corporate environment. Such indicators include metrics describing the time required to implement user scenarios, the level of platform availability, and parameters of operational reliability that make it possible to evaluate failure frequency and the speed of system recovery after incidents (table 2).

Table 2

Key technological metrics for evaluating the effectiveness of no-code solution adoption

Metric (with abbreviation)	Metric definition	Measurement focus	Relevance in no-code environments
Time-to-solution (TTS)	Average time required to deliver a functional user scenario from requirement definition to production.	Development speed and delivery efficiency	Reflects the acceleration of application delivery and flexibility of no-code platforms that change with business needs.
System availability	Percentage of time that is operational and accessible.	Platform stability and fault tolerance	Indicates the effectiveness of no-code platforms to support continuous operation within enterprise environments.
Mean time between failures (MTBF)	Average operational time between system failures or incidents.	Reliability and failure frequency	Assesses the robustness of visually assembled workflows and underlying runtime components.
Mean time to recovery (MTTR)	Average time required to restore system functionality after a failure.	Recovery efficiency and operational resilience	Showcases the utility of monitoring, rollbacks, and recoveries in no-code environments.
Integration latency	Response time observable in communication with external systems or APIs.	Integration performance	Very important to evaluate the usefulness of no-code in a variety of distributed or service-oriented environments.
Scalability index	Ability of the platform to maintain performance under increasing load.	Performance under scale	Reveals structural limitations when transitioning from MVP-level solutions to production-scale systems.

The technological impact of low-code/no-code solution adoption is documented in the **Forrester Total Economic Impact study of Microsoft Power Platform** (2024). Within the framework of a so-called composite organization, the study demonstrates that the use of the platform leads to a reduction of employee working time costs by up to 25 % across affected business processes and generates a cumulative time-related effect over a three-year analysis horizon; the report also presents a risk-adjusted conversion of the identified effects into monetary values [11].

Another example of an empirical assessment of the technological impact of no-code solutions is provided by a study published in the **MODELS Companion** proceedings (ACM/IEEE, 2024), which reports the results of a controlled experiment using a prototype no-code builder. The findings show that the median task completion time was 23 minutes for participants without prior experience and 19 minutes for experienced users, with the observed differences not reaching statistical significance [4]. In addition, most participants were able to learn the tool and create functional applications in less than one hour, demonstrating the potential of no-code approaches to lower entry barriers and reduce the time required to implement standard user scenarios when basic technological competence is present.

A study published in the European Research Studies Journal (2022) examines the implementation of a mobile application developed using the **no-code platform AppSheet** to optimize the parcel acceptance process in the warehouse operations of an e-commerce logistics company. Based on process modeling results, the authors report a reduction in the average acceptance time from 125 to 114.7 minutes, as well as a decrease in the total annual labor intensity of the target process by 28.4 days. In addition, the study demonstrates that the number of paper documents at the corresponding process stage can be reduced to zero through the digitalization of operations [7].

Another example of an empirical examination of the technology impact of no-code solutions was described in the study by Kerdar et al. (2025). The study was realized within the framework of the three-phase study design by providing a one-week training program for six study participants without an IT background, after which they had to create chatbots with the no-code platform's support – with all participants succeeding in developing four functional chatbots each. During the deployment phase, end users rated the developed tools highly on the System Usability Scale (SUS), with a mean score of 88.9 (SD = 11.2), indicating a high level of perceived usability and supporting the potential of no-code environments to enable non-professional developers to produce functional digital solutions under conditions of basic training and organizational support [5].

From an **economic perspective**, the effectiveness of no-code solution adoption should be assessed through a system of financial indicators that reflect changes in cost structure and the investment returns of IT initiatives. Of particular importance are metrics such as total cost of ownership and return on investment, which make it possible to compare the costs of implementing and maintaining no-code platforms with the achieved effects in the form of cost reductions, resource reallocation, and increased economic flexibility. In practice, the adoption of no-code solutions is associated with lower expenditures on recruiting and training IT personnel, reduced workload on internal IT departments, and optimization of application development and maintenance costs, which is especially significant for medium-sized and large organizations characterized by high costs of traditional IT systems (table 3).

Table 3

Key economic criteria for evaluating the effectiveness of no-code solution adoption

Economic metric (with abbreviation)	Measurement focus	Economic interpretation in no-code contexts
Total Cost of Ownership (TCO)	Aggregate costs of implementation, operation, and maintenance.	Enables comparison of lifecycle costs between no-code platforms and traditional custom development approaches.
Return on Investment (ROI)	Ratio of economic benefits to total investment.	Reflects the financial feasibility and overall investment attractiveness of no-code adoption.
Development cost reduction	Savings in application development and enhancement budgets.	Driven by accelerated delivery, reduced custom coding, and lower dependency on scarce IT resources.
Maintenance cost savings	Reduction in ongoing support and upgrade expenses.	Associated with standardized components and centralized platform management.
IT resource reallocation	Redistribution of internal IT effort toward higher-value activities.	Represents indirect economic gains through improved utilization of skilled personnel.
Payback period	Time required to reach the break-even point.	Indicates the speed at which investments in no-code solutions are recovered.

The economic impact of no-code solution adoption is confirmed in the **Forrester Total Economic Impact report for the Quickbase platform** (2023). Based on interviews with customers, the study reports a 315% return on investment over a three-year period, a net present value of $16.7 million, and a payback period of less than six months, as well as a 15 % reduction in inefficient operating expenses. These results can be interpreted as a decrease in total cost of ownership and an increase in the returns from the digitalization of business processes [8].

An impact on economics has also been found in a study done by **Nucleus Research** in 2025. In that study, emphasis was placed on interviewing clients who had adopted the Creatio platform, focusing on incorporating it as a no-code tool. On one hand, there was a reduction in technology expenses of 37 %, as well as a decrease in implementation time of 70 %, response time of 61 %, and manual data entry in sales operations of 17 %. These can, in total, define positivities in terms of time-to-value and cuts in implementation/operation economics as a result of decreased manpower requirements, as well as of technology expenses [2].

At the same time, while TEI studies provide quantitatively expressed estimates of economic effects based on cases from specific organizations, they primarily reflect a model-based "composite" company scenario and may depend on the industry and organizational context of adoption. Therefore, in order to derive a wider level of understanding regarding which parameters of effects and criteria of evaluation might be considered of critical importance regarding no-code solution selections, it is appropriate to rely on survey studies. As such, the **State of No-Code Development in 2024 report** published by Bubble proposes a series of quantitative evaluations regarding the importance of several adoption-level factors and criteria of evaluation regarding the performance of the selected solution, along with integration, scalability, security/compliance, and cost-related issues (fig. 1).

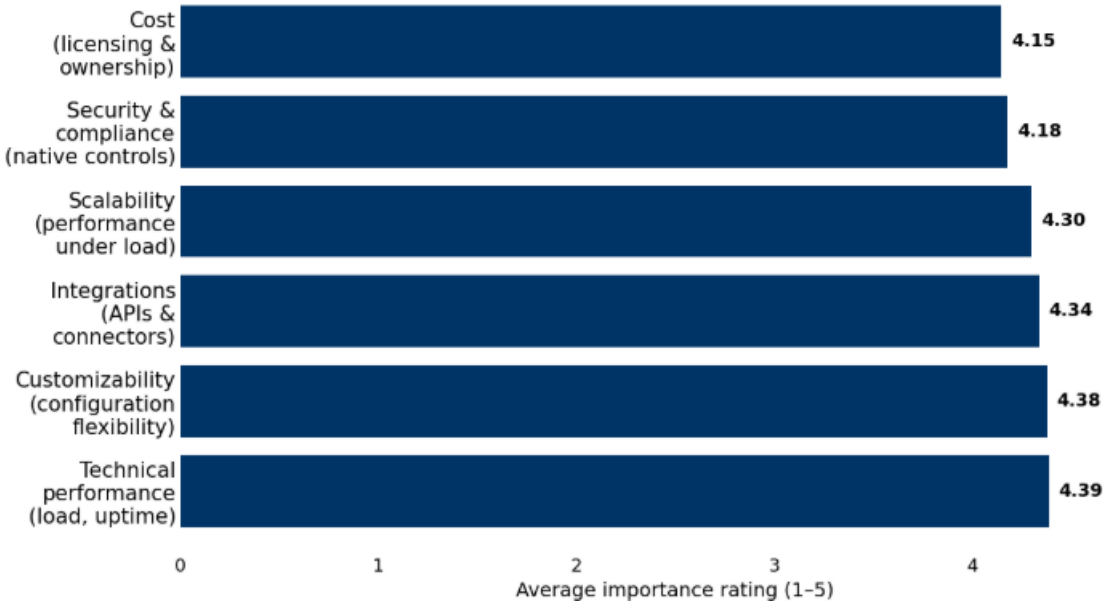

Figure 1. Assessment of the importance of key criteria for the adoption and selection of no-code platforms based on a user survey, Bubble, 2024 [10].

The author's practical experience, obtained through the implementation of no-code solutions in a corporate environment, confirms the possibility of achieving significant technological and economic effects when supported by appropriate architectural design. In particular, the design and deployment of a no-code platform resulted in an approximately 30 % reduction in digital solution development cycles, along with increased user satisfaction, which facilitated the scaling of solutions across multiple corporate projects.

Taken together, the data presented above allow the conclusion that the effectiveness of no-code solution adoption should be framed as a multi-criteria model, which amalgamates formal performance and reliability metrics with financial indicators and user-centered practical priorities. Empirical studies and case-oriented models illustrate measurable effects in the form of reduced Time-to-Solution, lower total cost of ownership, and faster return on investment, while survey results confirm that, in real life, the key evaluation factors remain performance, integration capabilities, scalability, security, and cost. This implies the necessity of taking a comprehensive and balanced approach to assessing no-code initiatives, drawing both on objective quantitative indicators and the context of real-world corporate deployment.

Technological and organizational implications of no-code solution adoption

The integration of no-code platforms into the corporate IT environment has a significant impact on information system architecture, the distribution of responsibilities between IT and business units, and the requirements for digital resource governance. These changes are consistent with contemporary approaches to the design of integrative digital environments, in which IT infrastructure is viewed as a flexible and adaptive system oriented toward accelerating digital transformation processes [12]. As a result, not only the approach to software development is transformed, but also the model for managing corporate digital assets, facilitating a shift from rigidly centralized IT practices toward more distributed forms of interaction.

One of the most pronounced consequences of no-code adoption is the **transformation of the role of IT departments**. With the active use of no-code tools, their functions increasingly shift from direct software development toward architectural oversight, information security assurance, and coordination of the digital ecosystem. IT units assume the role of internal regulators responsible for enforcing architectural standards, ensuring integration coherence, and maintaining the resilience of developed solutions. This shift aligns with modern architectural approaches to building scalable information systems, which place particular emphasis on managing component interconnectivity and controlling the application lifecycle [1].

The adoption of no-code approaches also contributes to **the democratization of technology within organizations** by expanding the involvement of business users in digitalization processes. The ability to independently create and modify applications without the participation of professional developers fosters the practice of citizen development, in which employees of functional units – such as marketing, logistics, and customer service – build solutions directly tailored to applied business tasks [13]. Such decentralization accelerates innovation and enhances the adaptability of business processes; however, it simultaneously increases the need for formalized mechanisms of coordination, architectural governance, and regulatory compliance assurance.

Against the backdrop of these changes, a **shift in workforce and competency priorities can be observed.** Demand is increasing for professionals with hybrid profiles who combine an understanding of business processes with basic technical skills for working on no-code platforms. This trend drives the transformation of corporate training programs, with greater emphasis placed on digital literacy, process-oriented thinking, and visual modeling skills. At the same time, professional developers and IT architects increasingly focus on higher-level tasks, including the design of resilient and scalable systems, the development of integration layers, and the governance of corporate data.

Therefore, the adoption of no-code solutions can be considered a starting point for the structural transformation of organizational information technology management. This transformation is characterized by a shift from hierarchical control models toward more network-oriented and decentralized management structures. In order to adapt to the above organizational change, a new governance model has to be created for the development of digital initiatives which is flexible, architectural, and strategic.

Conclusions

The results of the analysis confirm that the adoption of no-code solutions in corporate infrastructure enables measurable improvements across several dimensions: the average time required to implement digital functions is reduced, system resilience is enhanced through component standardization, and economic benefits are realized in the form of lower total cost of ownership and accelerated return on investment. At the same time, changes are noted in the organizational domain, including changes to specific positions in IT structures, increased participation among business users, and an increased call for individuals to have hybrid skills. As such, the need to build a new model for governing digital projects emerges, one based on the concepts of decentralization, architectural risk control, and security and compliance measures.

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DEVELOPMENT OF A TURBINE MACHINE DESIGN USING THE PARAMETRIC METHOD TAKING INTO ACCOUNT MULTI-PHYSICAL PROCESSES

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Abstract

The article analyzes the design of an energy machine. A parametric methodology for modeling and designing electro-mechanical energy converters is developed, which is based on the provisions of parametric design with one search criterion, or solution. The use of modern modeling tools is shown, which allows implementing such methods of system analysis as creating a criterion function with several indicators, using the properties of two or more physical parameters (electrical, mechanical, thermal, etc.). The structure of the elements of the power machine body is built using the multiparametric design method, the architecture of the blocks of the project components is determined, the relationships of the structural elements of the design approach and the sequence of calculations and design stages are substantiated. Using the example of the structural component of the body, the main elements are obtained that can be interpreted into the composition of an electric machine for the needs of the metallurgical industry. Emphasis is placed on the fact that, using parametric modeling and calculation and when creating additional software tools, it is possible to significantly increase the functionality of parametric design of individual elements of a power plant.

Keywords: electromechanical energy converter, parametric model, power plant, multiphysical processes.

1. Introduction

In the energy industry, one of the main components of equipment is turbine power machines and installations. The structural model of the algorithm for parametric design of electromechanical energy converters is a conceptual diagram that describes the logic and relationships between the design stages, taking into account numerous parameters (geometric, electrical, thermal, economic, technological, operational, etc.). Such a model is the basis for building optimized solutions in complex electromechanical systems [1].

The design stage is a complete and independent set of measures for developing a certain amount of design work, which may include calculations, modeling, drawings, experimental research and testing. The formation of the quantity and composition of the project depends on the developer and ranges from 1 to *m* design stages. We propose to distinguish the following stages of multiparametric design of electrical machines (EM) [2]:

1. Selection of the main dimensions of the electrical machine;
2. Calculation of the stator winding;
3. Calculation of the rotor winding;
4. Determination of the parameters of the electromagnetic circuit;
5. Determination of the operating characteristics of the electric machine;
6. Development of the structural part of the electric machine;
7. Development of the cooling system and its functional units.

The purpose of the article is to formulate the methodology, algorithms, and scientific and technical theory for performing parametric development of a turbine power machine, taking into account the multiphysical processes that arise in it during operation: electrodynamic, gas-dynamic, thermal, and mechanical.

2. Materials and research methods

In the actual theoretical study, we will consider point 6 – the development of the structural part of the electric machine.

Determining the geometry of the inactive (structural) zone of the electromechanical energy converter in parametric design is a design stage that covers the calculation and formation of parts of the EM that do not take a direct part in the electromagnetic conversion of energy, but ensure its mechanical integrity and cooling, meet transportation and installation requirements, ensure operational reliability and provide for the connection to the EM of various communications and support systems (connection to the electrical network, connection to water, hydrogen, lubrication and connection to networks of automatic control and monitoring of the technical condition of the EM) [3].

Figure 1 presents the developed graphical model for determining the geometry of the inactive zone of the electro-mechanical energy converter in parametric design. We have formulated four physical components of the design stage, which aims to determine the indicators of the structural part of the EM [4]:

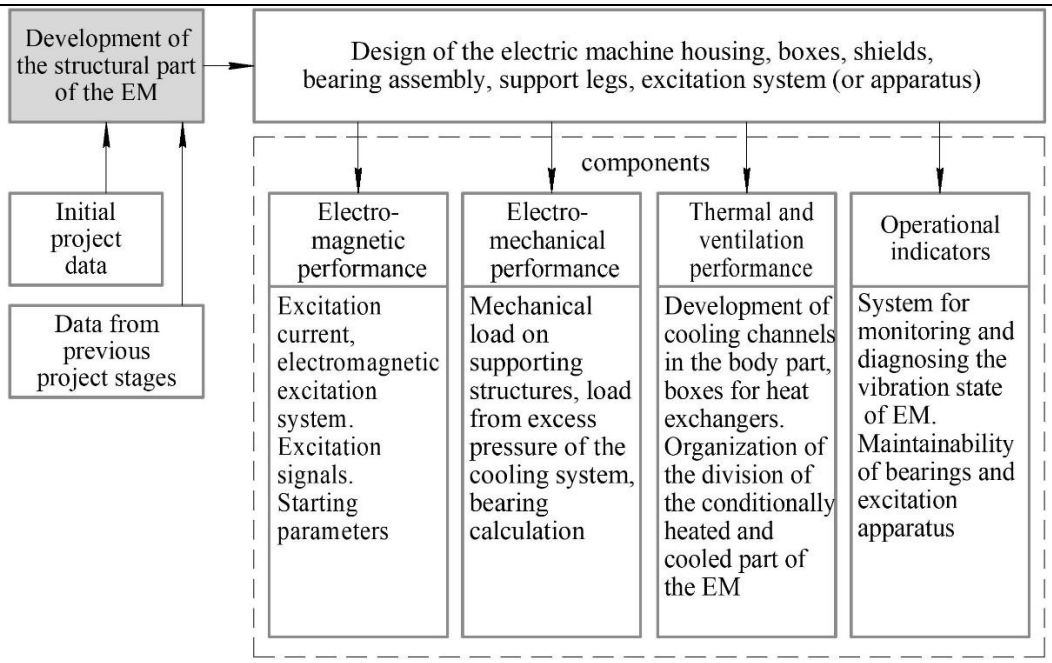

Fig. 1 – Structural model of the algorithm for determining the geometry of the inactive zone of an electric machine during parametric design

1. Electromagnetic indicators: i_v – excitation current of the thyristor excitation system, or brush holder apparatus, excitation control signals in the range of 4 – 20 mA, additional amount of electrical energy losses from the design features of the inactive EM zone;

2. Electromechanical indicators: G_{Fe} – mass of active steel of the EM stator, G_{Cu} – mass of the EM stator winding, Q_m – electrical energy losses in the EM bearings; reactions of the EM supporting parts (outer legs) to mechanical loads and vibrations during EM operation, development of the EM housing design taking into account excess hydrogen pressure (if provided) under the EM housing, and much more;

3. Heat and ventilation indicators: shape and geometry in the radial partitions of the stator, separation of conditionally hot cooling gas flows from conditionally cold ones, analysis of the hydraulic resistance of the gas that performs cooling and analysis of local places of temperature excess;

4. Operational indicators: determination of the technology for mounting the EM on the foundation, determination of the technology for inserting the rotor into the stator (for powerful turbogenerators, the development of technological equipment is required), execution of the design in compliance with the requirements for connection to hydrogen, water, lubricant, control circuits, etc. The mathematical model of parametric determination of the EM construction zone (Y_{korp}) is very broad in its multiphysical sense, therefore we limited ourselves to calculating mechanical loads from the EM's own mass, electrical power losses in bearings and EM excitation losses, for the reasons that these indicators are the most influential from the economic side of the design process:

$$Y_{korp}f(G_{FC};\ Q_v;\ Q_m) = \begin{cases} G_{FC} = G_{Fe} + G_{Cu}, \rightleftarrows\rightleftarrows\rightleftarrows \\ Q_v = \frac{2\cdot i_n + (i_n^2 \cdot r_2)}{\eta_v}, \\ Q_m = 255 \cdot \sqrt{\frac{G_2}{2} \cdot \frac{l_b}{d_b}} \cdot d_b^2 \cdot \left(\frac{f_n}{50 \cdot p}\right). \end{cases} \quad (1)$$

where, η_v – efficiency of the excitation device, a.u.; G_2 – mass of the rotor with the winding, kg; l_b – width of the bearing insert that is connected to the rotor, mm; d_b – diameter of the bearing insert that is connected to the rotor, mm; G_{FC} – total mass of the stator core G_{Fe} and the stator winding G_{Cu}, which are determined as follows:

$$G_{Fe} = 5.97 \cdot (D_a^2 - D_{z1}^2) \cdot l_1 + 7.62 \cdot z_1 \cdot h_{n1} \cdot \left(\frac{b'_{z1} + b_{z1}}{2}\right) \cdot l_1; \quad (2)$$

$$G_{Cu} = 1.5 \cdot r_1 \cdot (q_{a1} \cdot a_1)^2, \quad (3)$$

where, D_{z1} – is the stator diameter at the bottom of the stator groove, mm; D_a – outer diameter of the stator core, mm; b'_{z1} and b_{z1} are the width of the stator core tooth at the bottom of the stator slot, and the width of the stator core tooth at the inner diameter of the stator core, mm; h_{n1} – depth of the stator core groove, mm; z_1 – number of stator slots, pcs.; a_1 – number of parallel branches of the stator winding; q_{a1} – number of slots per pole and phase; l_1 – stator core length, mm; r_1 – radius of rounding of the corners of the copper elementary conductor of the rotor winding, mm;

For a better understanding of the geometry of the calculation zone of the power machine, we have depicted a schematic model in which we have shown the main designations, as shown in Figure 2.

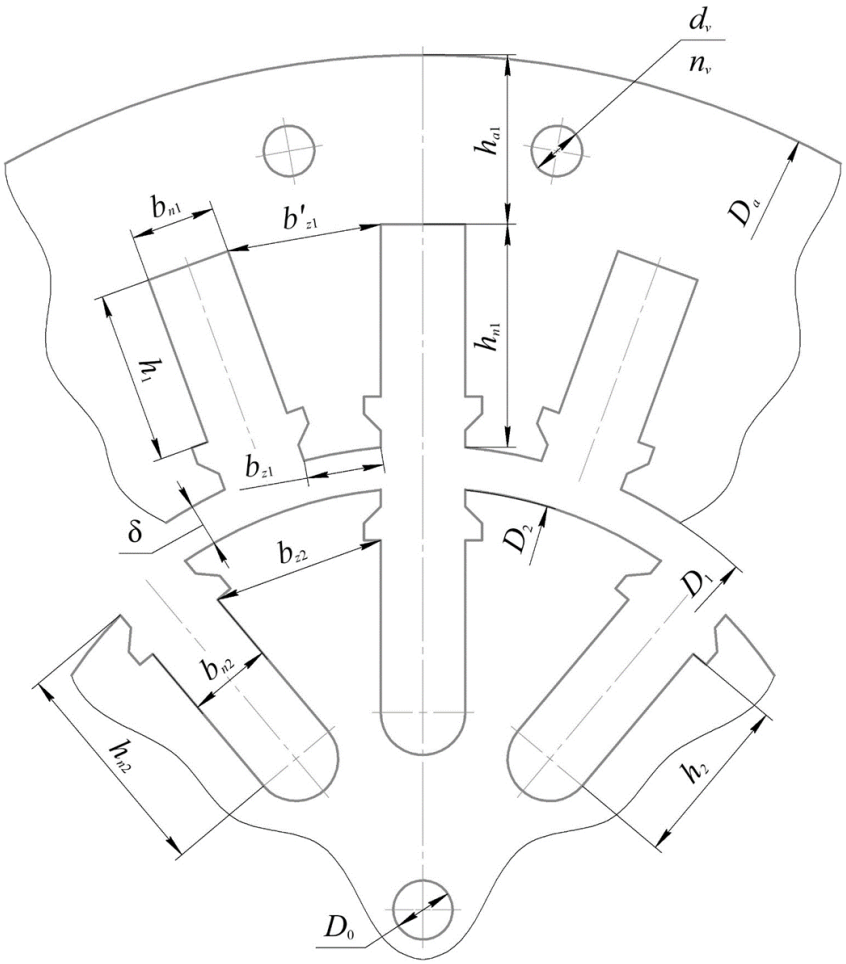

Fig. 2 – Graphical model of the computational domain in mathematical modeling of an energy machine

3. Results and discussion

Parametric construction of the housing part of the basic electric machine is a multifaceted engineering design process aimed not only at mechanical protection, but also at ensuring heat dissipation, vibration reduction, electrical insulation and compliance with operating standards in specified operating conditions. From the design point of view, the housing part of the EM has the following features [5, 6]:

- accuracy of tolerances (especially important when fitting bearings or interacting with axial structural elements);
- insulating properties (prevention of electric current breakdowns, especially in traction and high-voltage machines);
- electromagnetic shielding (in high-frequency motors, powerful EM or special-purpose EM).
- modularity or nodality (for maintenance: housing sectioning, the presence of hatches, hinged sections, etc.).

The synthesis of the body part of the basic EM using parametric design is graphically shown in Figure 3, and the execution of design work using this process will allow determining the layout of the main structural elements of the EM - the type of stator housing, the type of extension boxes (symmetrical, non-symmetrical, vertical, horizontal), the method of connecting the EM to the foundation, and the connection of the bearing assembly to the EM body.

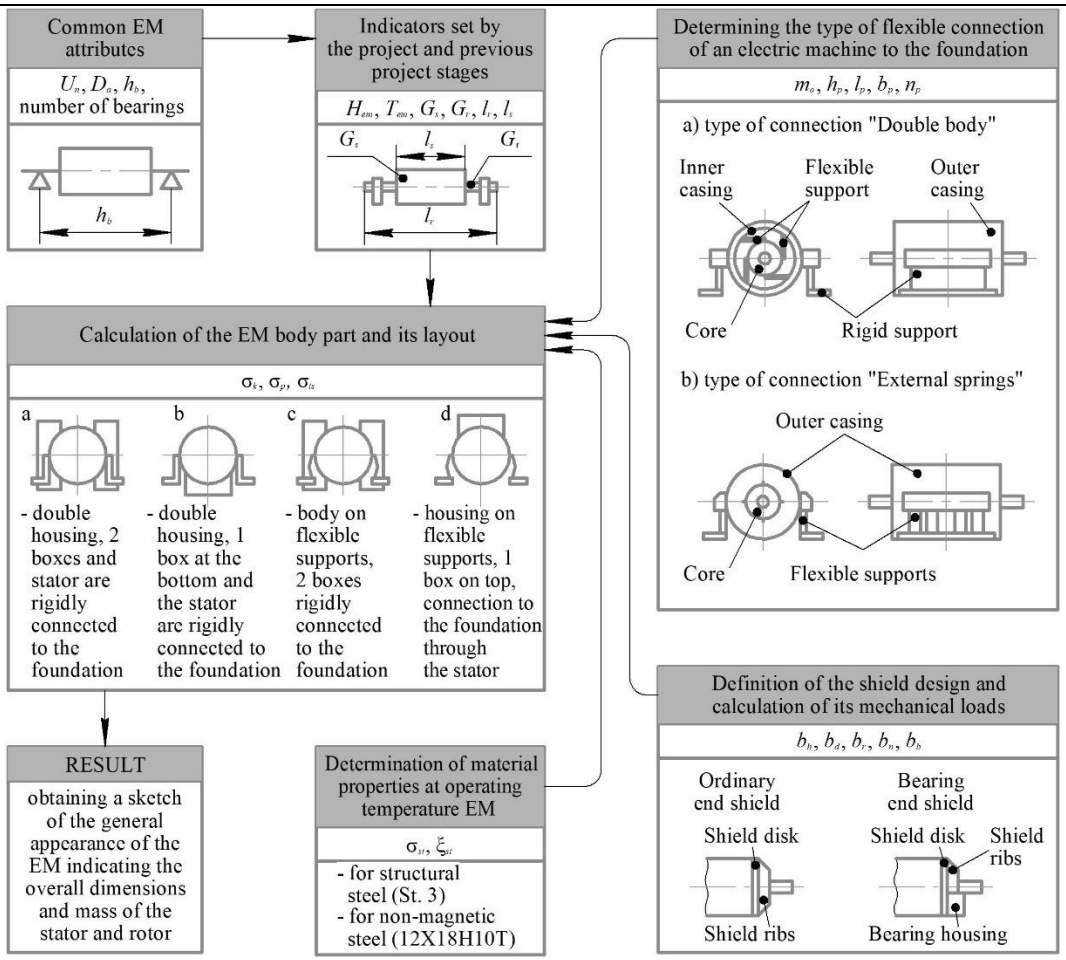

Fig. 3 – Construction of the body part of the basic electric machine using parametric design

General attributes of EM for the synthesis of the housing part differ from the construction of other nodes of the electromechanical energy converter by the presence of recommendation information on the distance between the bearings (h_b) which is due to the experience of designing EM of various types and is given in more detail in [7, 8], and the presence of variants of the design of EM with several bearings - one (when the function of the second bearing is performed by the adjacent bearing on the shaft line, for example, a turbine), or two.

Regarding the indicators specified by the project and data from the previous stages of design, the following information should be noted, which is necessary for the parametric construction of the EM housing: the indicator of excess gas pressure in the EM housing (H_{em}), the average temperature over the housing (Tem), the stator mass (G_s), the rotor mass (G_r), the total rotor length (l_r) and the total stator length (l_s). Without all these indicators, it is impossible to perform further calculations and parametric determinations.

The first parametric block is the definition of the type of flexible connection of the EM with the foundation - for powerful machines there are two types of such connection, this is the so-called double housing, when the stator core is stacked on prisms and transverse diaphragms, which together form a frame (housing) that holds the core with the winding, and this housing itself is installed in the outer housing using flexible elements (springs) that are located four pieces in different planes, and the number of such springs depends on the length of the stator core and its mass together with the winding. Thus, the limitation of stator vibrations occurs in the middle of the EM and the mechanical load is not transmitted to the external supporting structures of the EM that are connected to the foundation by a rigid connection. The second type of connection contains one external housing in which the stator core is stacked and the connection of the EM housing with the foundation occurs using flexible external supports (spring legs). Both design options are considered in detail in [9, 10]. Also in this block the reaction of the support (m_0) to mechanical loads from the EM is calculated, and the width (h_p), length (l_p), thickness (b_p) and number (n_p) of spring elements in the flexible support system are calculated.

In the next parametric block the design of the end shields is determined. In powerful machines these shields bear little or no mechanical load, especially when it comes to EMs with a capacity of 600 – 1000 MW. By and large, the design of the end shields can be divided into two types: a conventional shield, which consists of the main wall (disk) and radial stiffeners, to increase the resistance to mechanical loads. The second option is when the lower half of the outer shield is connected to the bearing housing, so that part of the shield performs the function of part of the bearing housing, and these two elements together perceive mechanical loads during the operation of the EM. Each design option has its own advantages and disadvantages, and

they are studied in detail in [11, 12]. In the scope of this block, it is necessary to calculate such indicators as: thickness (b_a) and diameter (b_d) of the end shield disk, thickness (b_r) and number (b_n) of radial stiffeners, and wall thickness of the bearing housing (b_b).

In the last multiparametric design block, it is necessary to determine the properties of the material under operating conditions (mainly temperature) – structural steel, and non-magnetic steel. The yield strength of the material (σ_{st}) and the coefficient of linear expansion (ξ_{st}) are mandatory.

In the final block, the mechanical load on the housing and box (σ_k), flexible springs (σ_p) and end shield (σ_{ts}) is calculated. Then the EM layout is selected, the most common are four layout options:

a) double casing, two vertical boxes for heat exchangers. The entire structure is rigidly fixed to the foundation. Such layouts are inherent in turbogenerators with a hydrogen or mixed cooling system, with a capacity of 200 – 500 MW;

b) double casing, one horizontal box for heat exchangers. The entire structure is rigidly fixed to the foundation. Such layouts are used in turbogenerators with a hydrogen or mixed cooling system, with a capacity of 300 – 350 MW;

c) single casing, two vertical boxes for heat exchangers. The box is rigidly fixed to the foundation, the stator is mounted on flexible supports. Such a design is used in turbogenerators with an air or mixed cooling system, with a capacity of 100 – 200 MW;

d) single casing, one box for heat exchangers, located on top of the stator. The box and stator are connected to the foundation through flexible supports of the stator housing. This arrangement is observed mainly in turbogenerators with an air cooling system, with a capacity of 20 – 120 MW;

As a result of performing all the above-mentioned measures for parametric design, we will obtain a sketch of the general appearance of the EM indicating its main dimensions and the mass of the stator and rotor. The main technical solutions for the arrangement of the main nodes of the EM will also be determined. An example of the structural parts of the EM housing, which can be obtained as a result of parametric synthesis, is shown in Fig. 4.

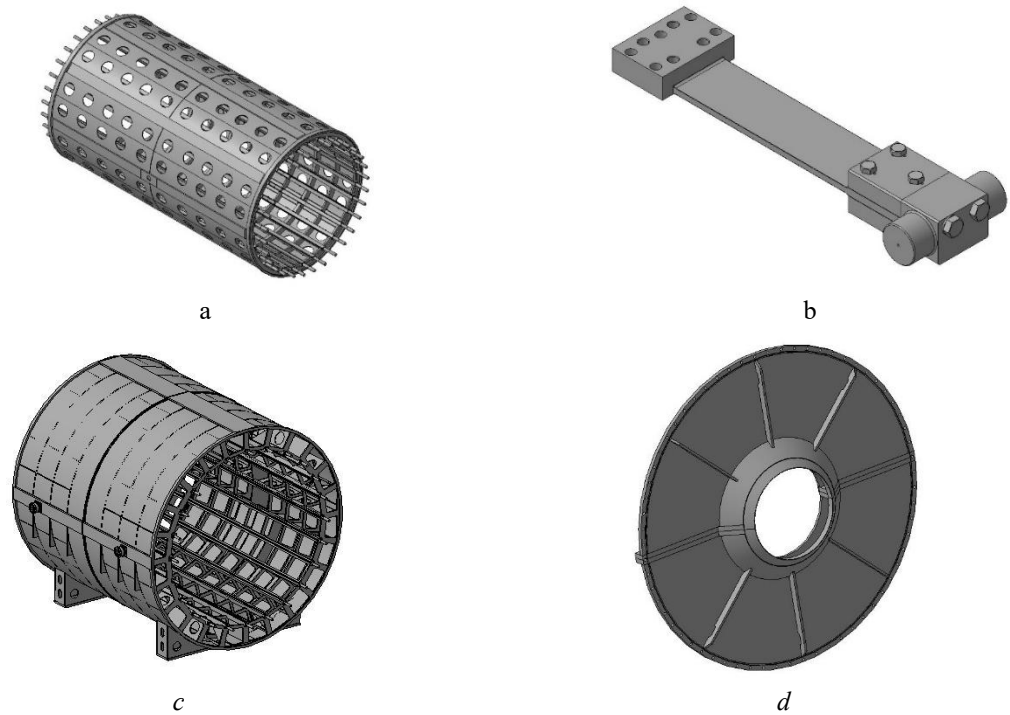

Fig. 4 – Elements of the body part of the electric machine obtained as a result of parametric construction: a – inner core body; b – inner flexible element (spring); c – outer stator body; d – outer end shield.

4. Conclusions

1. Multiparametric methodology for modeling and designing electromechanical energy converters has been developed, which is based on the provisions of parametric design with one search criterion, or solution. The use of modern modeling tools allows implementing such methods of system analysis as creating a criterion function with several indicators, using the properties of two or more physical parameters (electrical, mechanical, thermal, etc.).

2. The weaving of the body elements of the power machine was built using the parametric design method, the architecture of the project's component blocks was determined, the interrelationships of the structural elements of the design approach and the sequence of calculations and design stages were substantiated. Using the example of the construction of the body component, basic elements were obtained that can be interpreted into the composition of an electric machine for the needs of the metallurgical industry.

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